THE EXTERNAL ANATOMY OF SOME CARBONIFEROUS 'SCORPIONS' PART 2

by LEONARD J. WILLS

ABSTRACT. Part 2 is concerned with the anatomy of eight Orthostern 'scorpions', developed by the technique described in Part 1 (*Palaeontology*, **1**, 261–82). Virtually complete skins of two are described. The first is a paratype of *Buthiscorpius buthiformis* (Pocock), the description of which is supplemented from a second, less complete, example. The second is *Mazoniscorpio mazonensis* gen. et sp. nov. Each of the remaining five is incomplete as only half-nodules were available. They comprise a new species of *Buthiscorpius—B. major*; a new genus and species—*Wattisonia coseleyensis*; and three unidentifiable forms. Each provides valuable data about one or more organs: yet there is still no absolutely convincing evidence as to how any of them breathed. There follows a revised diagnosis and description of the Lobostern *Eoscorpius tuberculatus* Peach, here made the type species of *Benniescorpio* gen. nov. The paper ends with a brief discussion of the anatomical and ecological conclusions to be inferred from the descriptions in both Parts, followed by four supplementary notes correcting statements in Part 1 and describing new development-techniques.

INTRODUCTION

THE majority of Carboniferous 'scorpions' have been placed in Pocock's group Orthosterni (see Part 1, p. 267), because a few among them are known to resemble Recent forms in having unlobed parallel-sided sternites. I propose describing here details of the anatomy of eight Orthostern 'scorpions' etched out of ironstone nodules. After the descriptive part, a few general conclusions are stated, but I have made no attempt to revise our knowledge of Carboniferous 'scorpions' in general or to make a critical review of their taxonomy. In fact this last problem can never be successfully achieved until the type specimens have been developed to show details analogous to those achieved by the present etching technique.

I have throughout numbered the segments according to their position on the adult animal: Prosoma, carapace I to VI; Abdomen, mesosomatic VII to XII plus metasomatic XIII; Tail, metasomatic XIV to XVIII plus the sting. According to this scheme the genital operculum lies on the first adult mesosomatic segment (VII); whereas it is generally stated by zoologists to lie on the second mesosomatic (VIIIth) somite of the whole body, since the first (VIIth) or pregenital disappears in embryonic growth 'retaining in the adult only its neuromere, which becomes incorporated in the thoracic ganglionic mass as the 6th pair of its ganglia'. . . . 'The original number (12) of abdominal segments is restored in the course of embryological development by sub-segmentation of the 8th embryonic segment' (Petrunkevitch 1955, p. P68). Presumably Carboniferous 'scorpions' behaved in the same way, but there is, of course, no evidence. See also Størmer 1955, pp. P1, P6, re segmentation in Chelicerata in general and Merostomata in particular.

Repositories. B.M., British Museum (Natural History); B.U., Birmingham University, Geology Department; G.S.M., Geological Survey Museum, London; G.S.E., Geological Survey, Edinburgh; M.M., Manchester Museum.

[Palaeontology, Vol. 3, Part 3, 1960, pp. 276–332, pls. 46–57.]

List of abbreviations used in the illustrations. acl, anterior claw; *acs*, aculeus of sting; *app*, anterior plate of sternum of pecten; *ats*, anterior tarsal spur; *ap*, anterior process of carapace; *avn*, anterior V-notch of sternite; *b*, boss on rachis of pecten; *bch*, basal joint of chelicera; *bo*, border; *C* XIV–XVIII, caudal rings of adult segments XIV–XVIII; *c* 1–4, coxae of legs 1–4; *ca*, carapace; *ch*, chelicera; *cl*, claw; *cll*, claw-lobe; *cp*, coxa of pedipalp; *cr*, cephalic region of carapace; *d*, dagger; *ebc*, end of broken claw; *et*, eye tubercle; *f*, fulcra; f1–4, femur of legs 1–4; *fp*, femur of pedipalp; *frf*, free fingers; *go*, genital operculum; *gs*, pad or *Gehstachel*; *gr*, granule; *h*, hair; *hch*, hand of chelicera; *hpd*, hand of pedipalp; L, left; L.L. 1–4, left legs 1–4; *lm*, lamella of pecten; *lo*, lobe on metatarsus; *md*, mandibular process of coxa 1 or 2; *me*, median eye; *mg*, median groove of carapace; *mt*, metatarsus; *mts*, metatarsal spur (arising from base of metatarsus); *pa*, patella; *pa* 1–4, patella of legs 1–4; *pap*, patella of pedipalp; *pcg*, posterior cephalic groove; *pcl*, posterior claw; *pd*, pedipalp; *pe*, pecten; *pgs*, poison-gland of sting; *ppp*, posterior plate of sternum of pecten; *ps*, platform spine; *pts*, posterior tarsal spur; *pvn*, posterior V-notch of sternite; R, right; *Rch*, right chelicera; R.L. 1–4, right legs 1–4; *ra*, rachis of pecten; S IX–XII, sternites of adult segments IX–XII; SXIII, sternal plate of adult segment XIII; *se*, spinule on doublure of sternite; *set*, seta, bristle, movable hair; *sf*, sensory field; *sg*, sting; *sk*, stop-knob; *spe*, sternum of pecten; *spi*, spine; *st*, sternum of prosoma; TVII–XII, tergites of adult segments VII–XII; TXIII, tergal plate of adult segment XIII; *ta*, tarsus; *tas*, tarsal spur; *th*, teeth of pecten; *ti*, tibia; *tr*, thoracic region of carapace; *tr* 1–4, trochanter of legs 1–4; *tri*, sensory hair-bases (trichobothria); *trp*, trochanter of pedipalp.

SECTION A—ALMOST COMPLETE EXOSKELETONS

ORTHOSTERNI Pocock 1911
BUTHISCORPIUS Petrunkevitch 1953
Buthiscorpius buthiformis (Pocock)

Plates 46–48; text-figs. 1–9

Anthracoscorpius buthiformis Pocock 1911, pp. 24–28, pl. 1, fig. 2, pl. 2, fig. 1, text-figs. 6–8.
Eoscorpius buthiformis Petrunkevitch 1913, p. 35.
Eoscorpius buthiformis Petrunkevitch 1949, pp. 152–3.
Buthiscorpius buthiformis Petrunkevitch 1953, pp. 26, 32, figs. 31–34, 122.

Material. (i) Holotype, B.M. In.18596, Middle Coal Measures, Sparth Bottoms, Rochdale, Lancs. Pocock 1911, pl. 11, fig. 1, text-fig. 6; Petrunkevitch 1953, figs. 31–33, 122. (ii) Paratypes in British Museum, all from Coal Measures, Coseley, S. Staffs.: (1) In.31262, Pocock 1911, pl. 1, fig. 2*a* (here redescribed). (2) In.22832, Pocock 1911, text-fig. 8. (3) In.1555, Pocock 1911, pl. 1, fig. 2. (4, 5) Two specimens in Mr. Egginton's collection cited by Pocock 1911, p. 27 (present whereabouts unknown). One specimen, B.M. In.7883, figured as a paratype by Pocock (1911, text-fig. 7) has been made into the holotype of *Compsoscorpius elegans* Petr. (iii) Other material: B.U.720 (here described).

Remarks. In 1913, and again in 1949, Petrunkevitch assigned *Anthracoscorpio buthiformis* Pocock to the genus *Eoscorpius* Meek and Worthen, but in 1953 he erected *Buthiscorpius* for Pocock's holotype and all but one of his paratypes. Dr. E. I. White, with the sanction of the Trustees of the British Museum, has allowed me to develop both halves of one of the paratypes (B.M. In.31262) with the primary aim of discovering how a typical Orthostern 'scorpion' breathed. Unfortunately only negative evidence on this point has emerged. Each half is now encased in a transparent block of Marco, save for the two pedipalp hands, fragments of legs and comb, and part of the sting which are mounted as micro-slides.

The results of the development confirm Pocock's view that this specimen is conspecific with the holotype of his '*Anthracoscorpio*' *buthiformis*. As regards the generic identification it is best, in my opinion, to use Petrunkevitch's genus *Buthiscorpius* at present, pending a revision of the generic diagnoses of *Anthracoscorpio* Kusta (1884) and *Eoscorpius* Meek and Worthen (1868), on which also awaits the diagnosis of the Family Eoscorpioniidae to which undoubtedly all three genera belong. It may well prove impossible to distinguish the three genera, in which case *Eoscorpius* has priority over the other names.

Revised diagnosis, based on B.M. In.31262 and B.U.720. To the original diagnosis (Pocock 1911, p. 24) with additions by Petrunkevitch (1953, p. 32) can be added: Last caudal ring very long (one-third of whole metasoma), poison capsule rather small and probably somewhat shorter than 6th caudal ring. Sternum and coxae of the legs as described by Pocock in B.M. I.1555, with coxae 3 and 4 fused throughout the length of coxa 3. Genital operculum small. All legs with two claws and two tarsal spurs, and 3rd and 4th legs each with one large metatarsal spur. Pecten probably small. Sternites IX to XII unlobed, overlapping one another briefly and devoid of pulmonary stigmata.

Description of paratype, B.M. In.31262 (Pl. 46, 47; text-figs. 1–5)

Remarks. This specimen was collected by Egginton from the Coal Measures at Coseley, South Staffordshire. It was figured by Pocock (1911, pl. 1, fig. 2*a*) as a paratype of *A. buthiformis*, the figure incorporating data from both halves of the nodule and showing the chelicera more clearly than does the specimen.

As received the specimen lay in two halves of a nodule. One, now numbered In.31262A (and hereafter referred to as A), showed dorsal features seen from the ventral side with Right side elements appearing on the left (Pl. 46, fig. 1)—Pocock's pl. 1, fig. 2*a*, is reversed. On A a thin sliver of stone defined by a crack passing almost parallel to the surface and visible in the photo had been stuck on with shellac. I dissolved this and repaired with 'Seccotine'. The crack had severed the Right appendages which consequently broke away during the etching. The other half nodule, In.31262B, showed ventral features seen in dorsal aspect (Pl. 47, fig. 1). In both halves a good deal of very tenuous chitin was preserved, but in some places the surfaces were casts of the outside of the skin. This arrangement implies that when the nodule was split open the fracture passed between the dorsal and ventral skins, and that any intervening film of matrix was lost, for the dorsal features of A do not appear on B, and vice versa; e.g. the carapace is seen on A and the sternum and coxae on B.

There was no kaolinite reinforcement and only a very little iron pyrites, and the chitin proved to be very thin, transparent, and fragile. Consequently the mounted preparations are disappointingly fragmentary except in one or two cases.

After etching, the exterior of the dorsal surface (minus the sting) was displayed, the skin being preserved in places where it had escaped destruction on the original surface of fracture of the nodule (Pl. 46, fig. 2).

Approximate measurements in mm. Length of carapace, 3·5; abdomen, 8·5; tail, 11; sting, *c.* 4; total, 27.

The *carapace* is damaged at the forward end, but it can be seen that the sides converge slightly towards the front where the antero-lateral corners are rounded and united by a

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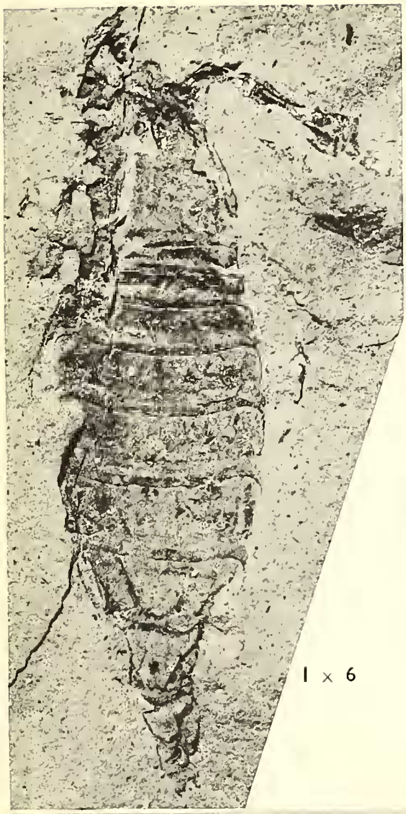
EXPLANATION OF PLATE 46

Figs. 1–5. *Buthiscorpius buthiformis* (Pocock), B.M. In.31262A and B. 1, Ventral view of the dorsal surface of A, as received. ×6. 2, Dorsal view of the dorsal surface of A, after development. ×6. 3, Dorsal view of the sting, Slide B.M. In.31262A/2, at about the same magnification as fig. 2. ×7·5. 4, Ditto. ×22·5 to compare with text-fig. 2. 5, Tip of the rachis of the comb with three teeth, each with a narrow sensory field. Slide B.M. In.31262B/11. ×60.

EXPLANATION OF PLATE 47

Figs. 1–6. *Buthiscorpius buthiformis* (Pocock), B.M. In.31262A, B. 1, Dorsal view of the ventral surface of specimen B, as received. ×6. 2, Ventral view of the ventral surface of specimen B after development. ×6. 3, Femur, patella, and hand of R. pedipalp. Slide A/1. ×15. 4, Tibia, metatarsus, tarsus, and claws of 1st or 2nd L. leg. Slide B/4. ×15. 5, Part of metatarsus, tarsus, and claws of 1st or 2nd R. leg. Slide B/1. ×15. 6, Metatarsus, tarsus, and one surviving claw of ? 3rd L. leg. Slide B/3. ×15.

For key to abbreviations see p. 277.



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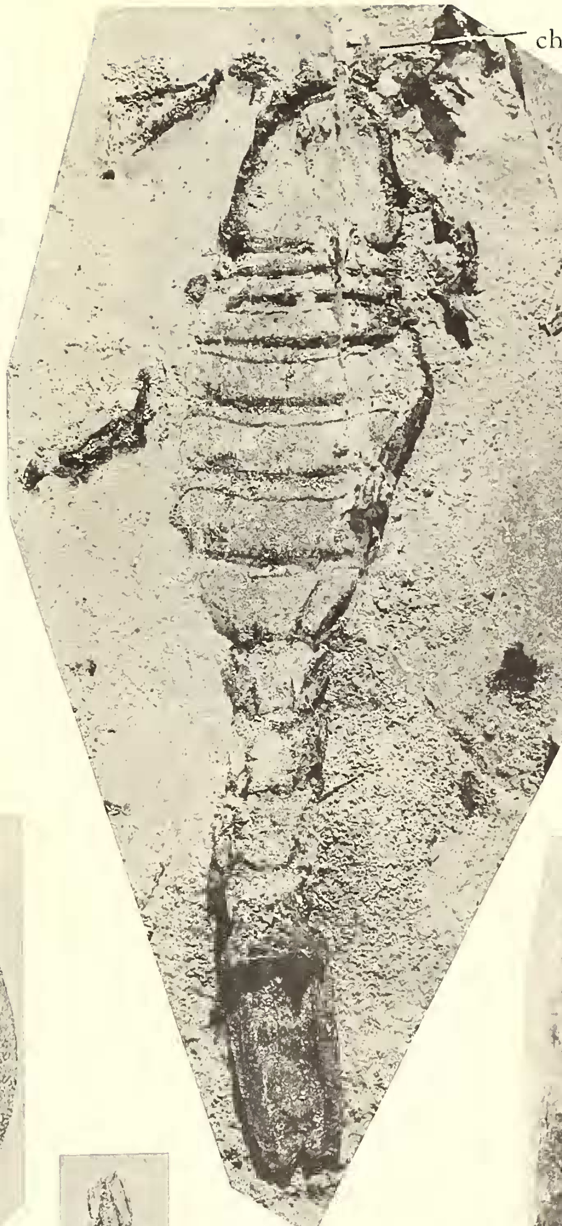

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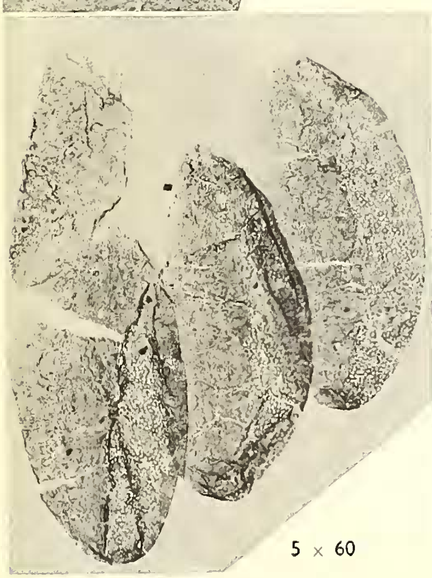
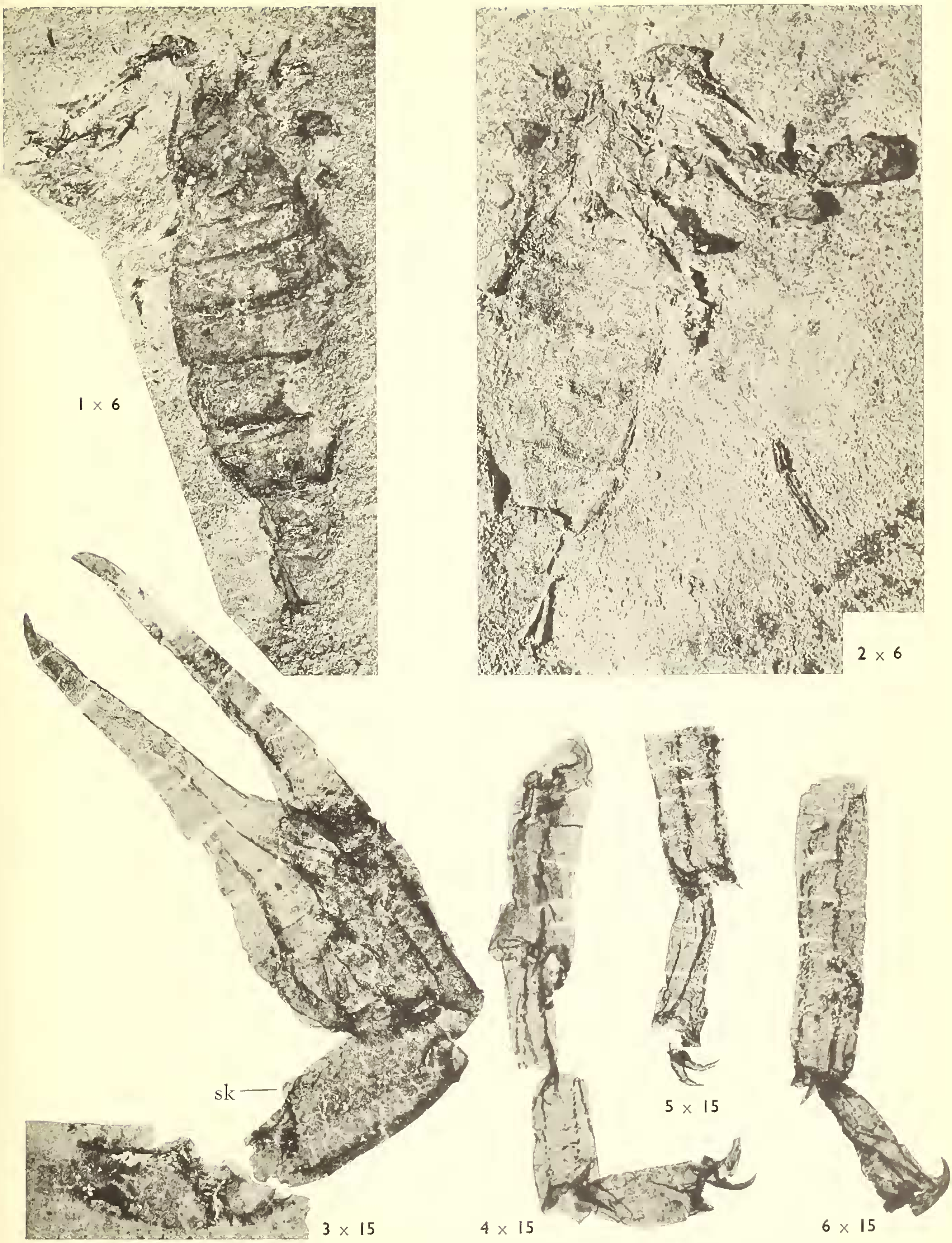


5 × 60

3 × 7·5

4 × 22·5

W I L L S, *Buthiscorpius*



WILLS, Buthiscorpius

curved anterior margin. The shield is somewhat arched, with a shallow median furrow that is blocked in front by the ocular tubercle which is situated about one-quarter of the length of the carapace from the front. The eyes are conspicuous (text-fig. 1): each appears to be a hemisphere with its polar axis pointing almost vertically. As Petrunkevitch (1953, p. 32) states, 'the space between the eyes is elevated'. This elevation is defined by a pair of small ridges separated by a median groove. On the right side of the carapace

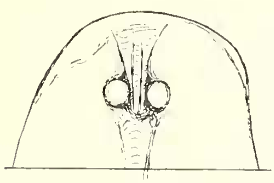


FIG. 1

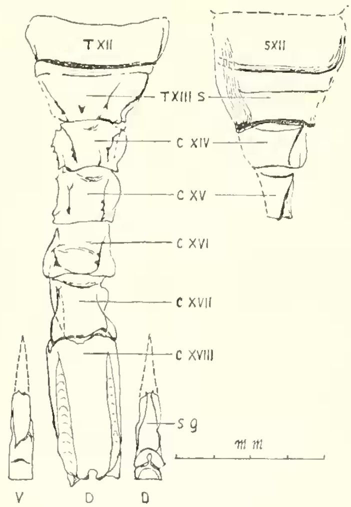


FIG. 2

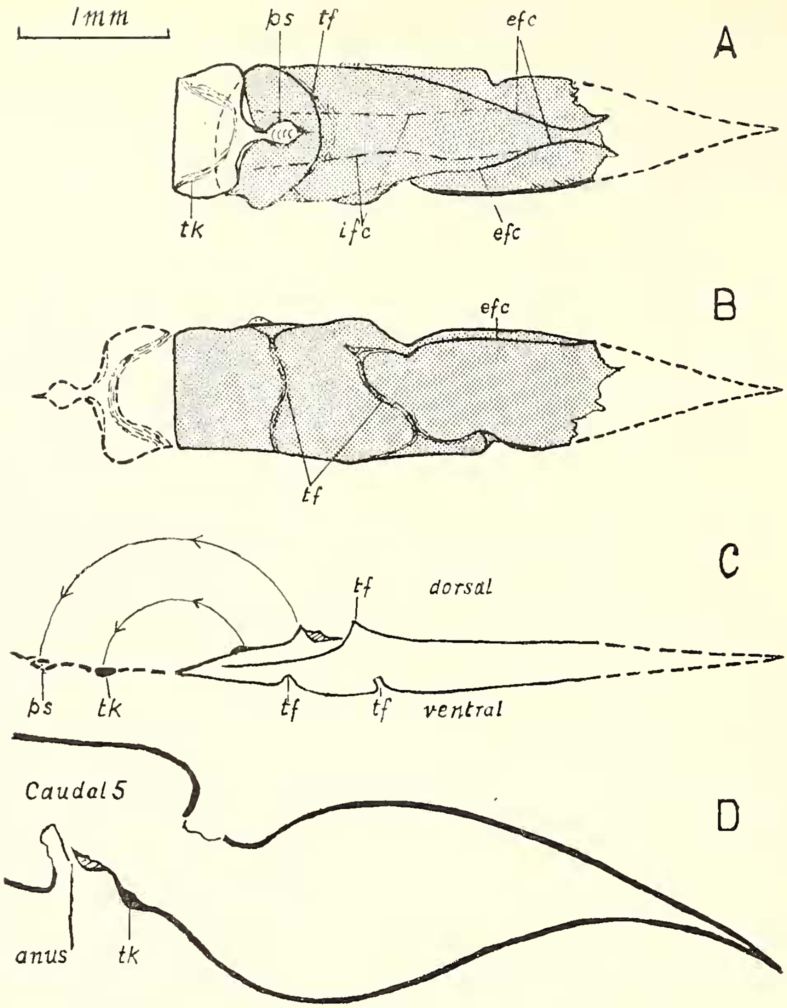
TEXT-FIG. 1. *Buthiscorpius buthiformis* (Pocock). B.M. In.31262A, after development. Front half of carapace to show the eye-tubercle with large median eyes separated by two diverging ridges and a narrow median groove. Behind the tubercle is the front end of the median furrow. $\times$ *c.* 10.

TEXT-FIG. 2. *Buthiscorpius buthiformis* (Pocock). B.M. In.31262A. Dorsal view of the metasomatic segments and sting. For key to abbreviations see p. 277.

the antero-lateral corner is fairly well preserved and shows no lateral eye ridges or lateral ocelli. The posterior margin is mucronate and passes into linear lateral margins. No ornamentation can be seen.

The *mesosomatic tergites* are quite normal, being very short in the front of the body and increasing in length so that tergite xii is at least twice as long as tergite vii. The width increases from tergite vii to tergite x, and then remains almost constant back to the articulation of tergite xii with the tergal plate xiii. The posterior margins are defined by lines of granular and mucronate tubercles, the anterior margins are linear. Wide strips of intersegmental skin are exposed, showing that the animal was entombed in a distended state.

The *metasomatic segments.* The dorsal surfaces of all the metasomatic segments etched out perfectly (Pl. 46, fig. 2), the end of the tail floating free in the acid (it now lies free in the Marco block, text-fig. 2); but only certain parts of the ventral surface of the tail can be examined, for it proved impossible to remove all the matrix from below the free-floating end in A, and only the skin of the 1st and of parts of the 2nd and 3rd metasomatic segments is preserved in B (text-fig. 2). The shapes and relative proportions



TEXT-FIG. 3. *Buthiscorpius buthiformis* (Pocock). B.M. In.31262B/2. The poison-capsule with the missing aculeus restored (broken line). A, Dorsal view of dorsal skin (stippled) and of inverted proximal process of the ventral skin (unstippled) with semi-annular thickening, *tk*, and ? periproctal skin, *ps*; transverse fold, *tr*; external and internal fold-crests, *efc*, *ifc*. B, Ventral view of ventral skin (stippled) with its proximal process (unstippled) restored to its original position. C, Sagittal section of specimen with its proximal part (broken line) restored as in B. D, Tentative restoration of the poison-capsule in relation to caudal ring 5 and the anus, in sagittal section.

of the metasomatic segments are fairly normal, the first four all having much the same length, the fifth being somewhat longer and the sixth (perhaps abnormally long) being about three times the length of the first. The first (Txiii) has the usual sharp taper backwards from the full width of the body to the narrow width of the caudal rings (the latter have been flattened and appear wider than they originally were). The whole segment consists of a dorsal and a ventral plate united by a wedge of pleural skin. The two plates taper sharply backwards to articulate with the first caudal ring. With the wedge of pleural skin they resemble a pair of old-style bellows. The sides of each plate are defined by marginal ridges which unite in blunt spines at the apex of each pleural wedge. On the dorsal plate there are also two sharp keels ending in formidable thorns, and a strong median spine. Both plates have linear anterior margins, that on the ventral plate lying much farther back than that on the dorsal, and with a correspondingly broader anterior border of intersegmental skin (possibly an adaption to the habit of inverting the tail over the animal's back).

Caudal rings XIV–XVI each have a pair of dorsal keels armed with spinelets and ending in a large thorn like those on TXIII. In CXVII and CXVIII the corresponding keels are wider, flatter, and free from spinelets and thorns.

Owing to flattening and to the obscuring by matrix, details of the sides and ventral surfaces of the caudal rings cannot be completely elucidated, but probably ventro-lateral keels marked the limits of the lower surface of each ring. The keels end in rather flat angular processes which are progressively larger as the end of the tail is approached, the pair on the last caudal ring being conspicuous and separated by a sinus, behind which the anus would lie.

The sting. The poison capsule lay symmetrically inverted over CXVIII. Unfortunately the aculeus itself was missing, probably as a result of my having ground away the back of the nodule a tiny fraction too much, the cut removing the dorsally projecting point of the sting. The rest of it, about 3 mm. long, etched out complete (Pl. 46, figs. 3, 4; text-fig. 3) as an almost cylindrical object. It is not absolutely certain which of its surfaces is the ventral one that, being inverted over CXVIII, was first laid bare by the etch, but the supposed dorsal side lies upwards on Slide A/2. Being quite transparent it can be examined from both sides and by reflected or transmitted light. The originally flask-shaped capsule was not flattened in fossilization, but was partially collapsed in a remarkably symmetrical way by the flexing of its curved sides inwards in two large and two small longitudinal folds, and transversely by one deep fold on the dorsal, and by two lesser ones on the ventral side; and the median proximal process on the ventral side was inverted so that its end pointed distally, text-fig. 3A, B, C. This process ends in a triangular piece that continues into thin plates which may be remains of the skin and muscles lying near the anus and connecting the sting to the last caudal ring.

Taking account of the inversion of the process, and the positions and sizes of the infolds (which can be traced out within the transparent sclerite), it seems likely that the capsule bulged dorsally and laterally near its proximal end, and that it had shallow lateral grooves (as occur in some Recent forms) which determined the position of the two conspicuous deep longitudinal infolds. On text-fig. 3D I have attempted a reconstruction of the actual sting as it would have appeared in sagittal section.

Organs of the ventral surface (text-fig. 4)

The original fracture that split open the nodule passed through the chelicerae and the basal parts of the pedipalp, and then between the carapace and the inside of the coxae of the legs and the sternum. In the mesosoma it passed between the tergites and the ventral organs (genital operculum, the sternum of the pecten and the four sternites). As a result the chelicerae and the coxae of the pedipalp were much damaged, and most of the two combs were lost. The etching of specimen B, however, revealed the outside or ventral surface of the coxo-sternal area and of the mesosomatic ventral organs in fair detail.

Chelicera. Only part of the hand of the chelicera shows in specimen A (Pl. 46, fig. 2, *ch*). It appears to be of normal proportions.

Pedipalp. Apart from the coxae, both pedipalps are fairly well displayed, and the hands were both extracted (Slide A/1, Pl. 47, fig. 3, and Slide B/2). The R. coxa is probably visible where it projects beyond the side of the carapace in A; the left one is seen in B to lie dorsally to the coxa of the 1st leg, but its shape is difficult to make out. The trochanter, femur, and patella are quite normal, the L. femur showing the row of granules noted by Pocock—'the femur of the left chela with an anterior granular crest, such as is present in most recent scorpions'. The whole of the R. patella (*pap*) is preserved in Slide A/1 (Pl. 47, fig. 3). It shows a 'stop knob' (see p. 304) on its anterior side and

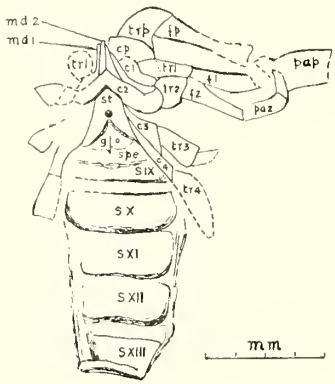


FIG. 4

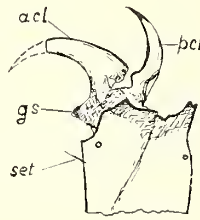


FIG. 5

TEXT-FIG. 4. *Buthiscorpius buthiformis* (Pocock). B.M. In.31262B. Ventral surface of body after development. Cf. Pl. 47, fig. 2. For key to abbreviations see p. 277.

TEXT-FIG. 5. *Buthiscorpius buthiformis* (Pocock). B.M. In.31262B/4. Claws and end of tarsus (in posterior view) of ? 2nd L. leg. Cf. Pl. 46, fig. 11. $\times c$. 60. For key to abbreviations see p. 277.

traces of small granules. Owing to crushing the original shape of the hand (*hpd*) is hard to determine, but the palm must have been stouter than the present outline would suggest. The fingers are somewhat longer than the palm and they taper gradually, to end in points slightly hooked towards each other. The biting edges are a little thickened, but devoid of granules. Under a high power of the microscope minute hair-bases, some perhaps trichobothria, can be seen near the tips and elsewhere.

In general the whole hand resembles that extracted from *B. major* sp. nov. (G.S.M. Za. 2926, Pl. 52, figs. 1, 2); but is relatively more massive and with shorter fingers. The whole pedipalp was large and massive in proportion to the legs.

Sternum of the prosoma (*st*) is six-sided, but is best described as pentagonal with the posterior side deeply excised, as a result of which the sclerite resembles a bluntly tanged arrowhead. Near the apex of the excavation there is a deep pit with its bottom pointing backwards. The sternum therefore agrees closely with Pocock's drawing (his pl. 1, fig. 2) of the ventral aspect of the coxo-sternal area of one of his paratypes (B.M. I.1555). Along the left side coxae 3 and 4 (*c* 3, 4) can be seen to abut against it, coxa 4 being much longer than coxa 3, and stretching back almost to the 2nd sternite. The two seem to be fused throughout the part in which they are adjacent to one another, as are the corresponding articles in Recent scorpions. This is an important observation, confirmed by what is seen in B.U. 720 (p. 288), because it negatives one of Petrunkevitch's tentative diagnostic characteristics of Eoscorpiidae—coxae of 3rd and 4th pairs of legs 'probably not yet grown together along their line of contact, retaining independent motion' (1955, p. P73), and shows that in the present genus at any rate the coxal arrangement was in this respect the same as it is today. Coxae 1 and 2 also conform exactly to the pattern found in Recent scorpions. The mandibular processes are well displayed, those on coxa 2 being the larger and lying side by side on the middle line. The other articles of the four legs are minute and their skin is so tenuous and devoid of any reinforcement that claws, spurs, and even individual joints were inevitably detached during the etching. Though several parts were recovered and mounted as Slides A/3–A/8 and B/1, B/3–B/8, it was impossible in some cases to be certain about their individual provenance, nor can one be certain that the surviving claws and spurs represent the original full complement. For these reasons only approximate estimates of the lengths of the appendages can be made. See Table, p. 289. The parts recovered (a few of which are illustrated on Pl. 47, figs. 4–6) do, however, compare so closely in shape or structure with the better preserved examples in B.U. 720 (Pl. 48, fig. 6; text-fig. 6) that it may be safely assumed that these limbs were organized on the same pattern. The detailed structure of the claws with their pad (*Gehstachel*) can be seen in Slide B/4 (text-fig. 5). No denticles can be seen on the claws, a feature possibly related to the small size of the individual.

Mesosoma. The *genital operculum* (*go*) is small, its two halves filling the posterior sinus of the sternum. The left half has been pushed under the right half far enough to damage and displace the median edges of both.

The *sternum of the pecten* (*spe*) appears to be short and possibly bilobed, but no details are visible. Remains of both combs were seen, but only a few teeth were recovered (Slides 10–12, Pl. 46, fig. 5). Each is a flattened sack, pointed at its proximal end and rounded distally, with a narrow sensory field thickly covered by peg-organs (Part 1, p. 274). The field occupies a lanceolate strip running from end to end. This arrangement is probably the normal one in Carboniferous 'scorpions', but the example here photographed reveals it more clearly than any of the other specimens so far found. What I saw of the combs suggested that each was short, with teeth few in number and attached to a narrow slight rachis—the whole resembling the comb of a Recent scorpion more than the fan-like ones found in *Lichnophthalmus*, *Pareobuthus* (Part 1), and *Benniescorpio tuberculatus* (Peach) (below).

The *sternites of adult segments* IX–XII, exposed on the original ventral half nodule (B) but not noticed by Pocock, revealed disappointingly meagre details after etching, probably because the ventral skin was extremely thin, crushed against the dorsal, and damaged when the nodule was split open. Sternite IX was better seen on the surface originally exposed (Pl. 47, fig. 1) than it is now after etching. It is short and ill-defined in front where it may have merged into the sternum of the pecten with but little marginal thickening of either sclerite. The others are much of a size, each about one-third longer than sternite IX. Each agrees roughly in length with its corresponding tergite. Traces of linear anterior margins can be seen here and there. The posterior margins are unornamented, but appear dark, mainly as the result of the infolding of the intersegmental skin in a deep doublure. It is this belt of overlap that showed up as a broad stripe between adjacent sternites on the internal surface as originally exposed (Pl. 47, fig. 1). The postero-lateral angles of sternites X–XII are rounded and clearly overhang (in ventral aspect) the pleural skin which here merges with the infolded intersegmental skin. There is no sign of any stigmata on any of the sternites or on the pleural or infolded intersegmental skin; nor can I detect any minute hairs or spinules on the infolded skin such as occur in *Pareobuthus* and *Lichnophthalmus* (Part 1). The depth of the intersegmental infold where one sternite overlaps the next one behind, although about one-third of the length of the sternite, would appear to be too small for an adequate cover to gills: how this animal breathed remains a mystery.

Description of B.U.720 (Pl. 48; text-figs. 6–9)

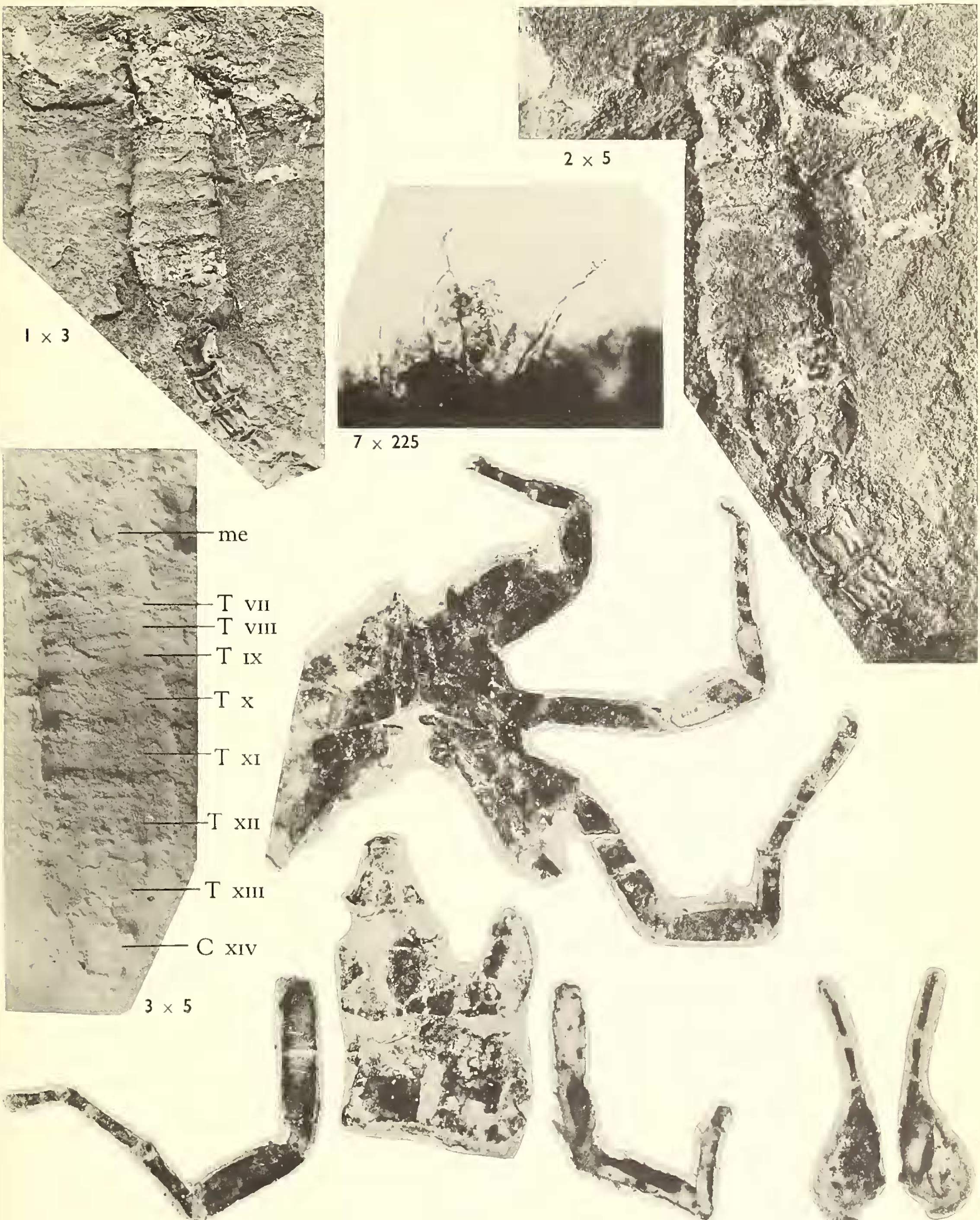
Remarks. This specimen appears to resemble the paratype of *B. buthiformis* just described (B.M. In.31262) so closely that it may confidently be referred to the same species. In particular it agrees in regard to dimensions and proportions, the shape of the carapace, the position of the median eyes, the apparent absence of lateral eyes, and in the organization of the coxo-sternal area. However, the front end of the carapace is not well preserved, and there are features towards its antero-lateral corners that in some lightings might be interpreted as lateral eyes. Were these certainly present the specimen would have to be referred to *Compsoscorpius* Petr., one species of which, *C. elegans* Petr., is based on another of Pocock's paratypes of *Anthracoscorpio buthiformis* (B.M. In.7883). The Birmingham specimen is particularly instructive because its legs were extracted almost intact with spurs, bristles, thorns, and spines still attached—features used extensively in the classification of Recent scorpions.

This was the first specimen to which, with Dr. Isles Strachan's help, I applied the embedding and hot-etching technique described in Part 1. The fossil, preserved in one half of a small ironstone nodule of the 'pennystone' type, was found by me many years ago amongst duplicate material of unknown origin in the Geology Department's possession. It had been almost certainly obtained from the Coal Measures of South Staffordshire, probably from above the Thick Coal at Coseley. Impressions of the dorsal surface as originally exposed were made in collodion, plastone, and dental wax, and it was photographed some years ago (Pl. 48, figs. 1, 2). As it was seen that bits of the original chitinous skin were preserved, I attempted to embed it in balsam with a view to etching with HF, but I was not satisfied and I dissolved off the balsam. Nothing further was done until 1956 when we took advantage of the development of the new transparent plastics to embed it in Marco and etched it with hot HCl. As a result, the following organs (some in a broken state) were isolated, and mounted: the sternites, the sternum, and attached coxae of the pedipalp and legs, the trochanter and hand (minus the movable finger) of the pedipalp, the remaining joints of three left legs, and parts of the right legs. In this instance, unlike the preservation in B.M. In.31262, the chitinous skin in some parts had been covered with, and cavities had been filled by, kaolin which functioned to keep the original shape and relief of the various parts even after they had been extracted. Embedded in the kaolin, however, were many bristles which have the appearance of having been torn away from the skin, as described and figured in Part 1 (p. 263; pl. 50, fig. 16), the figure being a photo of the metatarsus of the 3rd leg of the present specimen. At the end of the etching a very good transparent cast was obtained of the originally exposed surface, with a fair amount of chitin fragments embedded in it (Pl. 48, fig. 3).

EXPLANATION OF PLATE 48

Figs. 1–7. *Buthiscorpius buthiformis* (Pocock), B.U.720. 1, Dorsal view of the dorsal skin of the body and of the ventral skin of four caudal rings before development (cf. text-fig. 6A). ×3. 2, Ditto, to show carapace and eye-tubercle. ×5. 3, Dorsal view of Marco-cast after development. ×5. 4, Left pedipalp hand in dorsal view. Slide *k*. ×7½. 5, Ditto, in ventral view. ×7½. 6, Ventral view of ventral organs reassembled in approximately their original relative positions; based on Slides *a*, *b*, *d*, *h* (cf. text-fig. 6B). ×7½. 7, Hairs at the entrance to the mouth, probably on ventral side of the base of the chelicerae. Slide *g*. ×225.

For key to abbreviations see p. 277.



1 × 3

2 × 5

7 × 225

3 × 5

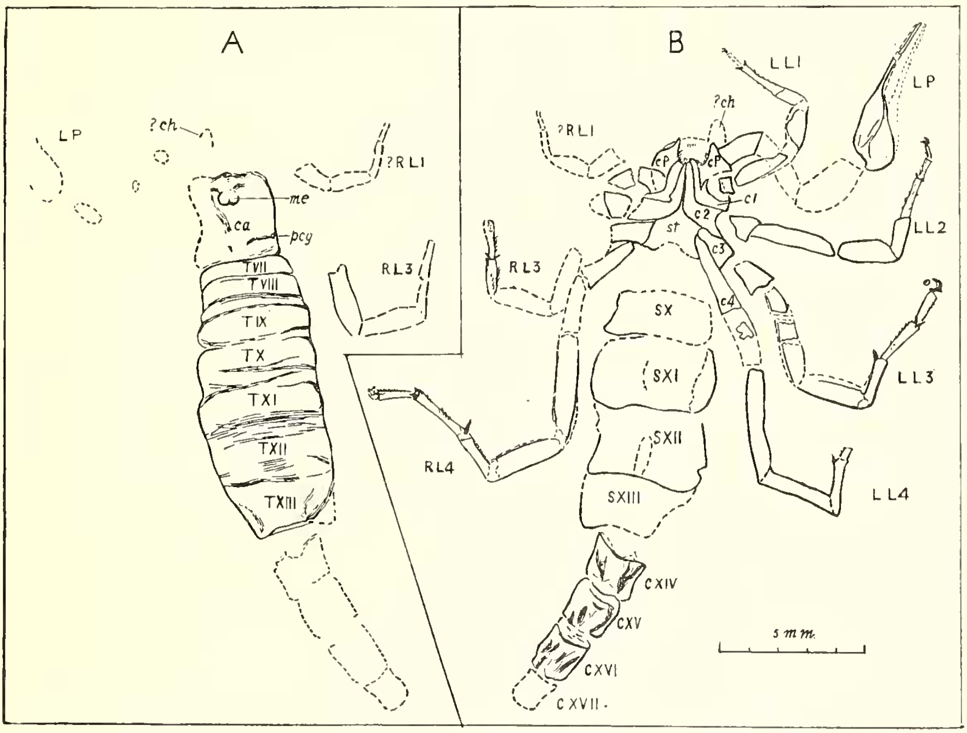
6 × 7½

4 × 7·5

5 × 7·5

WILLS, Buthiscorpius

Dimensions. The body was preserved in full relief, and consequently appears narrower in proportion to its length than it would had it been flattened. Approximate measurements and estimates given below agree closely with those of the holotype, of B.M. In.31262, and other paratypes. As scorpions go, these specimens represent either immature individuals or adults of a really small species, probably the latter. *Approximate measurements in mm.* Length of carapace, 3; of abdomen, $9\frac{1}{2}$; of tail (4 segments only), $7\frac{1}{2}$; whole body (estimated), 24–25; greatest width of carapace (apparent), 3·8; of mesosoma (apparent), 4·4; of mesosoma (estimate assuming it were flattened), 6·0. For dimensions of the legs see Table, p. 289.



TEXT-FIG. 6. *Buthiscorpius buthiformis* (Pocock). B.U. 720. A, Dorsal view of dorsal sclerites. B, Ventral aspect of ventral parts with appendages restored. Cf. Pl. 48, fig. 6. For key to abbreviations see p. 277.

Dorsal features of the body

The *carapace* (Pl. 48, figs. 2, 3; text-fig. 6A) was exposed as a poor internal mould, and practically all the chitin had been lost. It was strongly arched, and before development it appeared to be longer than wide, but afterwards it was seen to be almost square, or wider than long if allowance be made for the arching (compare Pl. 48, figs. 2 and 3). The shape of the damaged anterior margin appears to have been slightly emarginate (as in *Eoscorpius typicus* Petr.). The posterior margin is practically straight. In front of, and parallel to the latter at about one-sixth of the length of the carapace, is a slight transverse post-cephalic groove—a feature frequently found in fossil and Recent scorpions that may perhaps be connected with the attachment of the antero-posterior muscle (Werner 1934, p. 63, figs. 39, 40). (A similar groove in *Proscorpius* and *Palaeophonus* is interpreted by Petrunkevitch as proof that the first tergite was concealed under the carapace and that therefore these Silurian forms had seven mesosomatic tergites, not the usual six. This assumption appears to me to be entirely unwarranted, and to introduce a false basis to his classification in Petrunkevitch 1955, p. P69.)

A fairly large eye-tubercle carrying the two median eyes lies about a third of the carapace-length from the anterior margin. It is surrounded by an almost circular depression. The eyes are damaged but appear to lie closer to one another than in B.M. In.31262 and to be without intervening ridges.

The six *mesosomatic tergites* are best seen in Pl. 48, figs. 1, 3, which show them to increase greatly in length from front backwards; but their margins are poorly defined because all the chitin has gone, and we are looking at an internal mould (see text-fig. 6A, TVII–XII). The body was preserved fully distended with the intersegmental skin stretched out between the tergites, giving the impression of great length in relation to breadth. This power of extending the length of the tergum was probably possessed by many Carboniferous 'scorpions'. It, and the misleading appearance that may arise from it, is fully discussed on p. 320.

The dorsal plate of the 1st metasomatic segment (TXIII), poorly preserved, appears to taper unusually slowly. There are no strong keels on it. Possibly part of the sternal plate XIII is to be seen at the right postero-lateral corner.

External casts of the ventral sides of four caudal rings of the tail were originally present (Pl. 48, figs. 1, 2; text-fig. 6A). Partially flattened, they appeared stout and abnormally wide with traces of costal ridges, but the chitin having been lost no details could be seen. During preparation most of the tail was ground away, and now only the first caudal ring can be seen in the Marco-cast (Pl. 48, fig. 3). The fifth ring and the sting were not present in the half nodule.

Appendages and ventral features of the body

The *chelicerae*, originally poorly exposed, now show as casts in the Marco, but no details can be made out and no part was recovered.

The L. *pedipalp* was originally shown up by patches of white kaolin that indicated the presence of the trochanter, femur, patella, and hand, extended in all over a distance of about $7\frac{1}{2}$ mm. Of these joints the L. trochanter, together with L. and R. coxae, were recovered on slide *g* (Pl. 48, fig. 6; text-fig. 6B), and the L. hand, minus the free finger, on Slide *k* (Pl. 48, figs. 4, 5). The L. *coxa* is well seen in slide *g*. It has the normal shape, including the maxillary lobe extending towards the middle line and provided with fine hairs (see below). The *hand* (Pl. 48, figs. 4, 5) is very slender and produced into a rod-like finger. The whole hand measures 5·5 mm. (as compared with 7 mm. in In.31262), made up of about equal lengths of palm and fixed finger. Its maximum breadth is 1·5 mm. On the dorsal inner surface at about one-third of the length from the proximal end is a small but prominent knob, but little else can be seen on this side. On the other, one or two minute hair-bases are visible near the base and tip of the finger (as in *Buthiscorpius major* and *Mazoniscorpio mazonensis*, below), but there is nothing that can be regarded as a row of granules along the biting edge. The free finger was not recovered.

Any differences that may appear to exist between this not completely flattened hand and the crushed examples in B.M. In.31262 (Pl. 47, fig. 3), above, are due to differences in original size and in the mode of preservation. The long slender finger compares well in shape with those figured for several other supposed Eoscorpionids—*Eoscorpius typi-*

cus, *Compsoscorpius*, *Alloscorpius* and *Trigonoscorpius*, and with the Archaeoctonid genus *Eoctonus*; but in all cases the fingers appear more robust than does the one which has survived in this specimen.

The organs around the mouth (text-fig. 7). In Recent scorpions the entrance to the mouth is virtually a hollow tube-like filter formed by the chelicerae and labrum above, by the maxillary lobes of the pedipalpal coxae at the sides, and below by the mandibular processes of the 1st and 2nd legs. All of these may be thickly covered by brushes of forward-

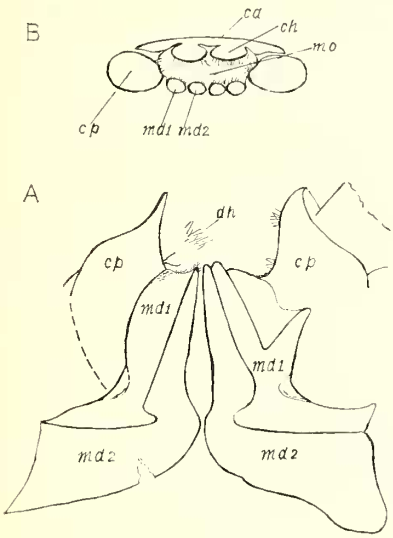


FIG. 7

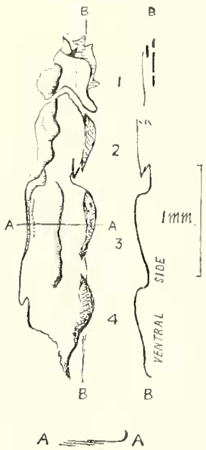


FIG. 8

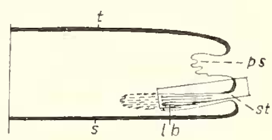


FIG. 9

TEXT-FIG. 7. *Buthiscorpius buthiformis* (Pocock). B.U.720. A, Mouth parts showing hairs attached or (*dh*) detached from the dorsal side of the mouth, now in the kaolin, originally on the chelicerae. Highly enlarged. B, Diagram-section through the mouth (*mo*). For key to other abbreviations see p. 277.

TEXT-FIG. 8. *Buthiscorpius buthiformis* (Pocock). B.U.720/*M*. ? Part of the lung-books—chitinous skin at the pleural ends of four sternites, drawn in dorsal aspect with lighting from right to emphasize the ends of overlapping films of chitin and the blotchy chitin on right (heavy shading); and sections along AA and BB. Cf. text-fig. 9.

TEXT-FIG. 9. *Buthiscorpius buthiformis* (Pocock.) B.U.720/*M*. Hypothetical sections through the right half of a body segment to illustrate the position of Slide /*M* (cf. text-fig. 8), which is outlined by a small rectangle, in relation to a possible pulmonary pouch with a stigma (*st*), a sternite (*s*), and a tergite (*t*); laminate respiratory organ, diagrammatic (*lb*); pleural skin (*ps*).

directed bristles and hairs, forming a perfect filter to exclude all solids. In the fossilization of the present remarkable fossil, this entrance became filled with ironstone, but after solution of the latter it now appears (on Slide *g*) as an open cavity into which project short fine hairs attached to the chitin of the pedipalpal coxae and to the mandibular processes of the 1st and 2nd legs, and some similar hairs lying in the kaolin and not attached to any visible chitin, but in a position corresponding to the chelicerae and/or labrum (Pl. 48, fig. 7; text-figs. 6B, 7A, B).

Taken in conjunction with the hairs actually still attached to the chelicera of *B. major*

(Pl. 52, fig. 4), the present specimen suggests that some at least of the Carboniferous 'scorpions' employed the same method of feeding as do their present-day descendants, and one that would appear more appropriate in terrestrial than in aquatic animals (the aquatic *Eurypterus fischeri* Eichw., however, also had hairs around its mouth. See Holm 1898.)

The coxae of the 1st and 2nd legs (text-fig. 6) closely resemble the corresponding parts in Recent scorpions in possessing the strong mandibular processes referred to above, but differ in that the process on the 2nd leg is not markedly larger than that on the 1st. This difference from Recent scorpions was noted by Pocock (1911, p. 28) in his description of a paratype of his *Anthracoscorpio buthiformis* (B.M. I.1555). The same characteristic appears also in B.M. In.31262 (above and text-fig. 4). The posterior edges of the coxae of the second leg meet in an angle of 120°. As these edges coincide with the front of the sternum, they reveal its anterior shape.

The sternum and the coxae of the 3rd and 4th legs. The *sternum* was badly broken during development, and is now represented only by some small fragments in slide *g* (Pl. 48, fig. 6; text-fig. 6, *st*); but at one stage it was well exposed, and I noted it as being roughly rectangular, wider than long, with a forwardly directed anterior side and a nearly straight or very slightly emarginate posterior side. In view of the 120° angle between the posterior edges of the two second coxae, noted above, its true shape must have been roughly pentagonal, and somewhat different from that found in B.M. In.31262 (above, p. 282; text-fig. 4). It agrees, however, with the shape shown by Petrunkevitch as characteristic of Eoscorpiidae (1955, fig. 40/1) which is based on one of Pocock's paratypes of *Anthracoscorpio buthiformis* (1911, pl. 1, fig. 2, B.M. I.1555). See also Petrunkevitch 1953, fig. 34.

Coxa 3 is stout and short, barely half the length of the slender *coxa 4* to which it is completely fused. Both abut against the sides of the sternum.

This specimen confirms the findings in B.M. In.31262, namely that the shape of the sternum, the relation of the coxae to it, and the fusion of coxae 3 and 4 are all essentially the same as in Recent scorpions.

Other parts of the legs. In death the *legs* had been flexed under the body and were fossilized in this position. Supported by sheaths of kaolin, those that were still buried in the ironstone etched out almost intact, but, with the exception of the 1st L. leg which survives on Slide *g*, they broke off at various distances from their bases. The fragments belong to L. legs 2–4 and R. legs 3 and 4. They were extracted and mounted as Slides *a*, *b*, *d*, *e*, *f*. On Pl. 48, fig. 6, photographs of them have been placed in approximately correct relationship to one showing the coxae and 1st L. leg on Slide *g*. It will be noted that the distal parts appear in the figure as if they lie in the same plane as the coxae, whereas they were preserved disposed in planes more or less at right angles to it, and in postures exactly analogous to those assumed by the legs of any dead scorpion of today. The legs increase in length from in front backwards (Table, p. 289), the 4th being twice as long as the 1st. When fully extended it would have been capable of reaching to the end of the 2nd caudal ring. The general shape and proportions of the different articles of the legs are shown in text-fig. 6 and on Pl. 48, fig. 6, to be extraordinarily like homologous features in Recent forms. Clearly this particular Carboniferous 'scorpion' was already adapted to moving about easily on land, a feat that *Lichnophthalmus* (Part 1) with its stiletto heels could never have achieved.

As in Recent forms, each leg terminated in a pair of non-denticulate curved claws diverging from an angular basal pad. This was well seen in the 3rd L. leg, but the slide (*a*) was subsequently damaged and the part lost in remounting. It agreed exactly with the claw-parts on the 3rd leg of In.31262 (text-fig. 5).

The absence from *B. buthiformis* of the denticles that occur on the claws of all the larger 'scorpions' here described is perhaps to be correlated with the small size of the species.

TABLE

Lengths in mm. of the body, the pedipalp, and legs (exclusive of the claws) of *B. buthiformis*

	Body (less tail)	*Pedipalp arm+hand*	*1st leg*	*2nd leg*	*3rd leg*	*4th leg*
Holotype B.M. In.18596 .	12·1	? 11·5 ? 7·0+4·5	..	..	..	..
Paratype B.M. In.31262 .	12·5	14·5 8·0+6·5	? *c.* 7–8	? *c.* 8	? *c.* 9	*c.* 15
B.U.720	12·5	*c.* 12 ?6·5+5·5	8·2	11·3	13·3	16

The three distal articles (tarsus, metatarsus, and tibia) of each leg carried a variety of immovable spines and spinelets on keels, crests, and round their distal ends, together with movable hairs, thorns, and bristles (some ? trichobothria); but the three proximal ones (patella, femur, and trochanter) are, like the coxae, virtually devoid of any such. Of considerable interest is the occurrence of two *tarsal spurs* sited on the skin between the tarsus and metatarsus of each leg and of one *metatarsal* spur on the skin between the metatarsus and tibia of the 3rd and 4th legs (these names for the spurs have been adopted here as indicating the positions on the leg, whereas the terms 'tarsal spur' of English authors and 'Grunddorn' and 'Tarsalsporn' of Werner 1934, p. 35, do not). Now, in the classification of Recent scorpions the number and distribution of such spurs are characteristics of a whole genus or even a family. When I later developed *Mazoniscorpio* I found the number and distribution of spurs to be just as in the present case, and I suspect that the same is true for all the Orthostern Carboniferous 'scorpions'. Further, it is most remarkable that this arrangement can be matched exactly in Recent scorpions, but only in members of one family—the Buthidae.

The distribution of fixed spines, movable hairs, and bristles on each of the three distal articles of the legs can be epitomized as follows:

Tarsus with some small rather blunt bristles (? rudimentary thorns or *Dornen* of Werner), especially a large group on the distal half of leg 3.

Metatarsus with two rows of short bristles on legs 1–3, scattered bristles on 4, a distal group of bristles on 3 and 4. Two rows of short spinelets on 2 and 3, but none on 1 and 4. One end-spine on all legs.

Tibia with no rows of bristles, but a few scattered ones at the distal end on legs 2, 4, and ? 3.

A few small but conspicuous hair-bases can be seen on the tarsus of legs 3 and 4, on the metatarsus of all four, and on the tibia of legs 1–3. These may perhaps be regarded as the thecae of slender sensory hairs (? trichobothria), because in no case has a bristle survived in attachment to them, whereas there are many short bristles to be seen (above) which do not appear to spring from any definite hair-bases. It is interesting to note that among Recent scorpions trichobothria are not known to occur on the legs except in immature individuals.

The *genital operculum* and *pecten* were missing.

The *sternites*. Scraps of sternites I and II are mounted on Slides *l* and *n*, part of sternite II and most of III and IV on Slide *h*; and on slide *m* bits of them which were extracted from the pleural region between the sternites and tergites. The chitin of the sternites is very thin and devoid of ornament, hairs, and hair-bases, except for the minutest of prickles and hair-bases on the posterior and postero-lateral margins (Slides *h* and *l*). Sternites III and IV are roughly rectangular, slightly wider than long, with the postero-lateral corners rounded and posterior margin slightly emarginate. In Slide *n* this edge can be seen to be double for a very short distance forward, suggesting that one sternite overlapped the next behind, but the preservation is not good enough to allow us to determine the extent of overlap or to see whether or not there are pulmonary stigmata on the postero-lateral border, where they occur in the Triassic scorpion *Mesophonus* (Wills 1947); but it can be stated definitely that there are no stigmata on the external surface of any of the four sternites, so far as they are preserved (and this covers the greater part of sternites III and IV).

On Slide *m* was mounted a part of the pleural intersegmental area lying between the tergites and sternites. It is sketched in supposed dorsal aspect on text-fig. 8. On it there are four narrow strips of chitin (1–4) lying lengthwise along one side. They are somewhat blotchy, and darker and less transparent than the rest, and may represent the skin originally dorsal to the ends of the sternites. Nos. 2–4 stand up at right angles to the general plane of the specimen which seems to consist of two or three sheets of excessively thin chitin, the top sheet being continuous with the upturned part of No. 3 (see section A–A on the text-figure). I find it impossible to interpret the specimen with any degree of certainty, but I am inclined to regard what I have sketched (it lies upward on Slide *m*) as possibly respiratory structures originally lying dorsal to the R. ends of the four sternites, the shortest (top of figure) being the most anterior. If this hypothesis is correct, it would suggest that a pulmonary pouch and stigma existed between the external end of each sternite and the corresponding dark strip which was part of the pleural skin, and that in this pouch lay the thin chitinous laminae, forming some kind of lung-book. This speculative explanation is shown in text-fig. 9.

MAZONISCORPIO gen. nov.

Type species *M. mazonensis* sp. nov.

Mazoniscorpio mazonensis sp. nov.

Plates 49, 50, and 51, figs. 4–6; text-figs. 10–13

Holotype. B.U.721A, B, and C. Pennsylvanian, Mazon Creek, Illinois.

Remarks. The holotype is on permanent loan to the Geology Department, Birmingham University, from the Botany Department, University of Illinois, Urbana. The large nodule had been split in two roughly on the plane of the dorsal skin. The half labelled A originally displayed dorsal features seen in ventral view (Pl. 49, fig. 1) with grooves on the carapace appearing as ridges. After development it showed the external aspect of the dorsal skin (Pl. 49, fig. 2) except where that had been lost. Here it presented a mould of the inside of that skin on the Marco-cast. This has now been filled in and become a transparent Marco-block, 721A. The last segment of the tail and the sting were sawn off the nodule and developed separately. They were mounted in Marco on glass as 721C.

The half labelled B originally exhibited bits of dorsal skin, the natural cast of the inside of the dorsal skin, and indications in places of ventral organs, all seen in dorsal view (Pl. 50, fig. 1). After development it displayed many ventral organs in ventral view together with traces of the dorsal features as impressions in the Marco-cast (Pl. 50, fig. 2; Pl. 51, fig. 4). The Marco-cast has now been filled in as a Marco-block, B.U.721B.

The specimen was remarkable for its large size—about 7 cm. in length—and is so now for the complete preservation of almost every part, like an insect in amber, within the three Marco-blocks. The missing organs, except for parts of the ventral skin which is probably present but crushed on to the dorsal tergites, can be accounted for as follows. Part of one sternite fell away, but was recovered; and I extracted and mounted the left halves of two sternites in order to be able to examine them in transmitted light. I also recovered the end of one leg, fragments of the finger of one pedipalp, and a few tiny bits of other parts.

Diagnosis of genus and species. Large Orthostern 'scorpion', *c*. 70 mm. long and 11 mm. wide at widest tergite XI; dorsal side and prosomatic appendages conforming to the pattern of a Recent buthid scorpion with a long sting, large chelicerae, powerful pedipalps, and slender legs which have the buthid arrangement of spurs.

Carapace almost square with a median groove and two cephalic and two postcephalic arched lobes; median eyes small on front of an eye tubercle of two kidney-shaped bosses separated by a narrow groove, close to front margin of carapace; front part of carapace has deep doublure and is coated with fine hairs, rear part covered irregularly with small granules which are tiny on the postcephalic lobes. Tergites coated with fine hairs, otherwise unornamented. Tergal plate XIII and all caudal rings with strong dorsal keels, caudal ring XVIII short, sting long, flask-shaped with strongly curved aculeus.

Chelicerae large, projecting in front of the carapace for a distance equal to not less than half its length. Pedipalps powerful. Coxo-sternal area with a bluntly pentagonal sternum; mandibular process of 1st leg larger than that of 2nd, coxa 4 about twice the length of coxa 3; legs relatively slender, coated with fine hairs, two denticulate claws and two tarsal spurs on each leg; one metatarsal spur on 3rd and 4th legs.

Genital operculum with two pairs of arched lobes and a narrow median ridge carrying a flattish leaf-shaped plate. Sternum of pecten ill-defined, combs large, each with at least sixteen teeth. Sternites roughly rectangular, overlapping backwards. Sternite IX ill-defined, possibly triangular behind. Sternite X lamellate, in two halves, each half with deep posterior doublure, rounded at postero-lateral corner and here covered externally and on doublure by minute hairs; no stigmata. Sternites XI, XII similar to SX, but possibly not divided into two halves. Sternal plate XIII large with pronounced rounded postero-lateral corners, possibly half the plate was covered by SXII.

Description. The carapace measures 8 mm. in length and 9 mm. in breadth behind. The abdomen is 20 mm. long and 10 mm. wide at its widest part (tergite XI). The tail, as preserved in A, is *c*. 20 mm. in length, but a few mm. were lost in the sawcut that severed the last caudal ring and tail. The last caudal is 5 mm., and the sting can be estimated at not less than 15 mm. These figures give the total length of the 'scorpion' as 68–70 mm.

Dorsal surface

Prosoma. Carapace (Pl. 49, fig. 3; text-fig. 10). This is nearly rectangular, with a slight taper forwards. The front corners are rounded and devoid of lateral eyes. The anterior margin has a slight median projection. The whole front end has a very deep doublure extending back at least as far as the hind end of the eye-tubercle. The carapace was originally rather strongly arched with a deep median and two slight postcephalic grooves, which together divide the shield into two lobes of the cephalic region in front, and a pair of postero-lateral postcephalic lobes behind. The median groove narrows in front where it is continued as a narrow furrow between the two halves of a small circular eye-tubercle, situated very near to the front margin of the carapace which it overhangs. The small eyes, originally hemispherical and looking upwards, occupy the front half of the tubercle. The posterior margin of the carapace is a broad band of thick skin rounded at the corners, with a few small hair-bases. Many parts of the skin of the shield are ornamented by numerous small granules which show up most prominently on the folds at the sides of the grooves. The postcephalic lobes, however, are covered with similar, but quite tiny granules. Numerous hair-bases, some with short setae still attached, occur on the external surface of the R. anterior corner (some also are probably on the doublure). In addition, the original existence of a coating of minute fine hairs over much of the front end is evidenced, where the chitin of the shield is missing, by the actual hairs (now attached to the Marco-cast) which were torn from their bases but left in the rock when the skin was broken away. A similar coating of fine hairs has been observed in other parts of the animal (below).

EXPLANATION OF PLATE 49

Figs. 1–7. *Mazoniscorpio mazonensis* gen. et sp. nov., B.U.721A. 1, Ventral view of dorsal skin, as received. Photographed under alcohol. ×2·7. 2, Dorsal view of dorsal skin and R. appendages after development. ×2·7. 3, Chelicerae, carapace, and tergite VII, after development (cf. text-fig. 10). ×5. 4–7, The ends of the four L. legs, fig. 4 being the 1st and fig. 7 the 4th, photographed during development. ×7.

For key to abbreviations see p. 277.

EXPLANATION OF PLATE 50

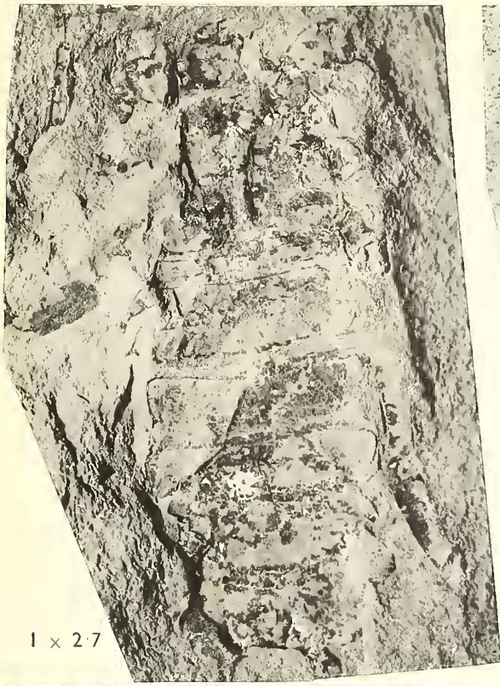
Figs. 1–5. *Mazoniscorpio mazonensis* gen. et sp. nov., B.U.721B except figs. 3, 4 (fragments derived from 721/A). 1, Dorsal view of dorsal skin and in places traces of ventral features. As received, ×2·2. 2, Ventral view of the ventral organs of anterior part of the body before detachment of sternites, and of the Marco-cast containing bits of chitin and impressions of dorsal and ? ventral skin of the posterior end (cf. text-fig. 12). ×5. 3, Tip of the fixed finger of the hand of the R. pedipalp. Slide B.U.721A/4/6. ×40. 4, Metatarsus with spines and tarsal spurs, tarsus and claws of 2nd or 3rd leg, showing hairs and hair-bases. Slide B.U.721A/3. ×14. 5, Fragments ? left side of sternite ? XII, figured on Pl. 6, fig. 6; photographed by transmitted light to show hairs on both surfaces. Slide B.U.721B/1. ×40.

For key to abbreviations see p. 277.

EXPLANATION OF PLATE 51

Figs. 1–3. *Buthiscorpius major* sp. nov. G.S.M. Za 2926. 1, As received. Ventral view of dorsal surface, photographed under alcohol. ×3. 2, 2nd Marco-cast often etching. Dorsal view of dorsal surface of body, with tergites VII–XII and two fragments of the sting. ×3. 3, 1st Marco-cast repaired, dorsal view of dorsal surface of body and tail, after etching. ×3.

Figs. 4–6. *Mazoniscorpio mazonensis* gen. et sp. nov. 4, B.U.721B. Progress photo of ventral organs to show the L. pedipalp and L. legs with claws and spurs. Some parts outlined in ink. ×2·1. 5, Ventral view of the skin of the L. ends of sternites ? X, XI, with the posterior margin and median continuation of ? Sx. Slide B.U.721/2. ×6·8. 6, Part of the L. side of ? Sxii having hairs on both sides (see Pl. 50, fig. 5). Slide B.U.721B/1. ×6·8.



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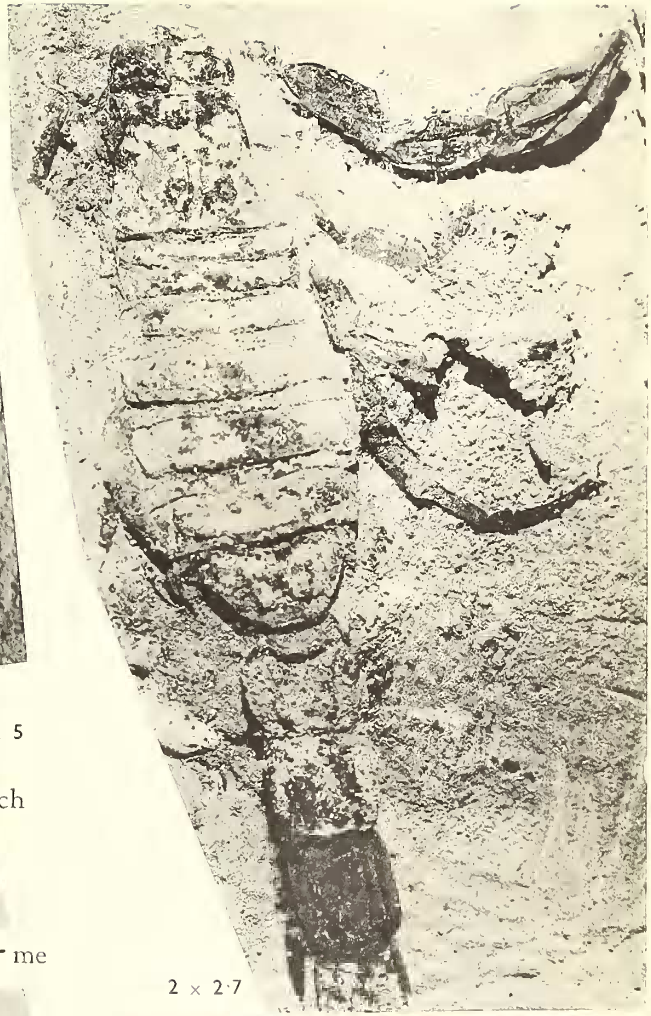

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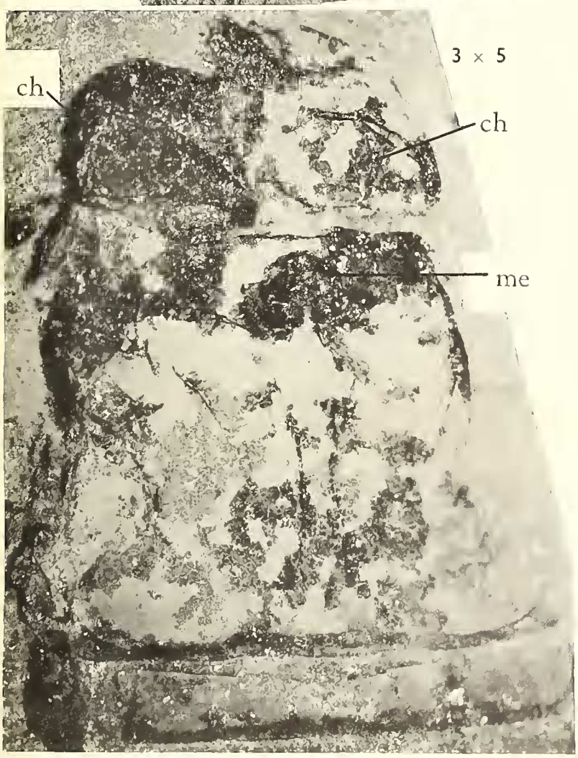


3 × 5

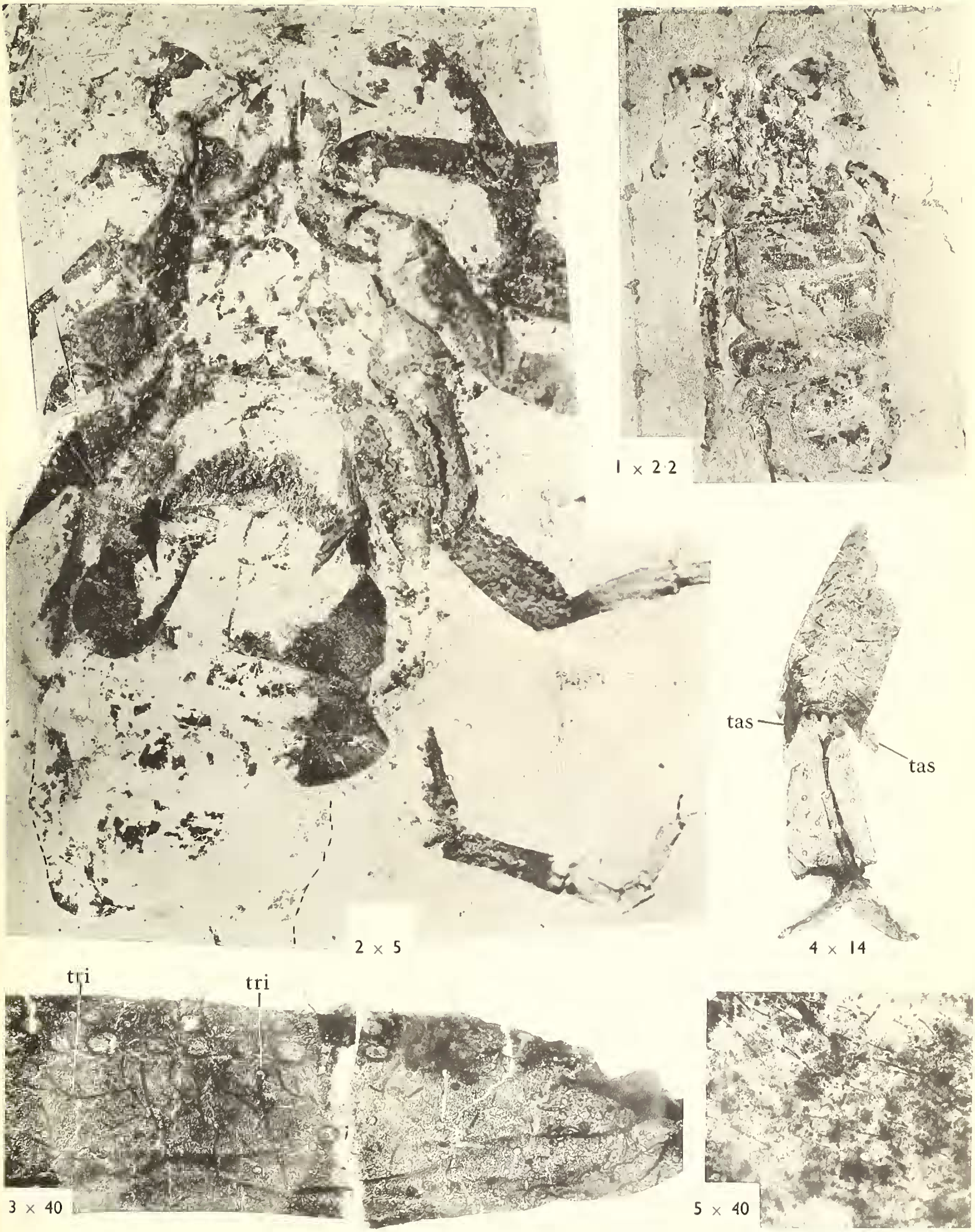
4 × 7

5 × 7

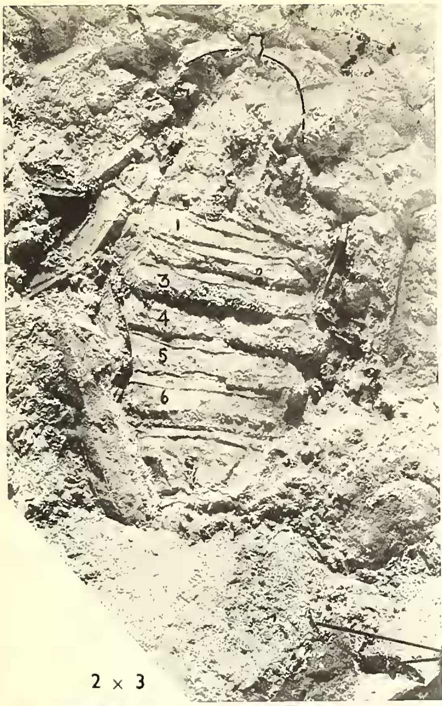
6 × 7

7 × 7

WILLS, *Mazoniscorpio*



WILLS, *Mazoniscorpio*



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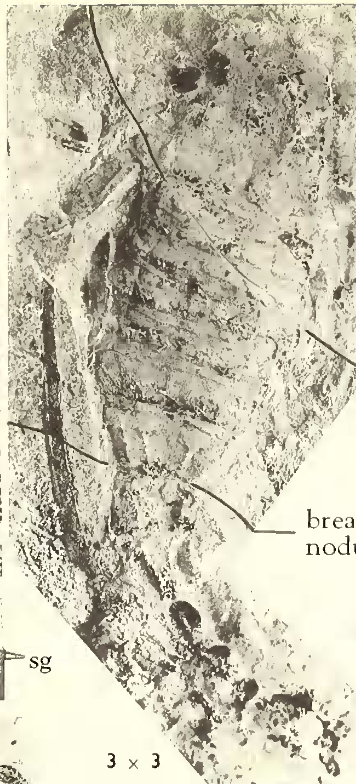
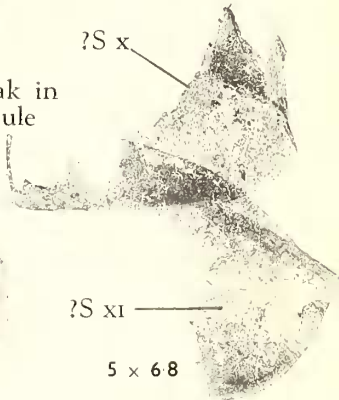


3 × 3

6 × 6·8



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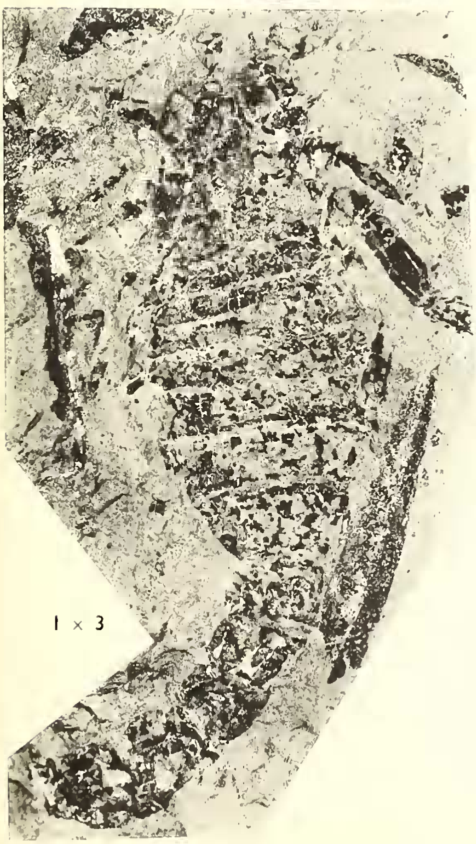
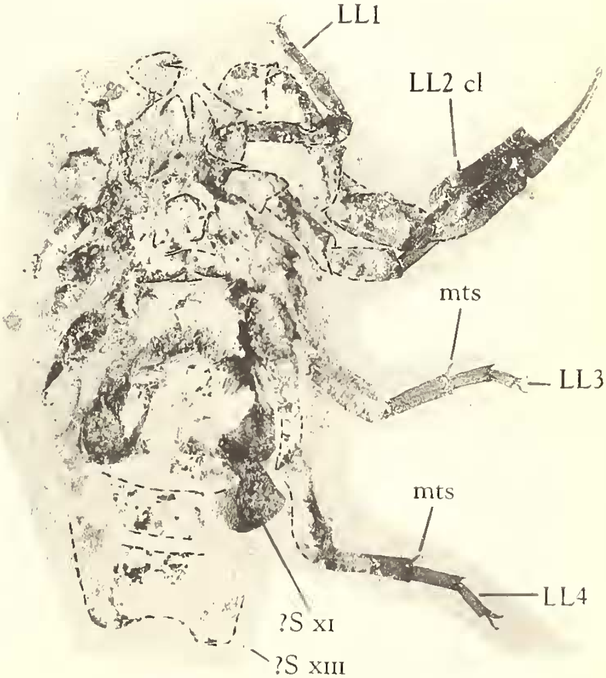


1 × 3



4 × 2·1

WILLS, *Buthiscorpius* and *Mazoniscorpio*

Mesosoma. Tergites vii–xii (Pl. 49, figs. 1, 2). These are quite normal in shape and proportions, increasing in length backwards from 1 mm. to 3 mm., and in breadth from the carapace to tergite xi and then decreasing slightly. Each is bounded by a linear anterior margin and an unornamented posterior margin formed by a narrow infold or doublure which passes into the wide anterior border of the next segment. These margins

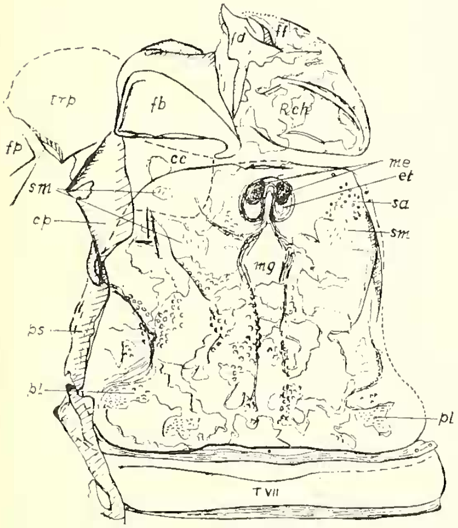


FIG. 10

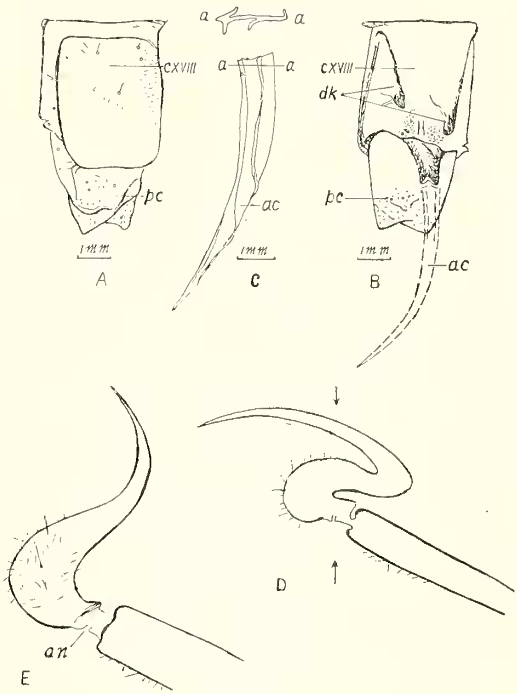


FIG. 11

TEXT-FIG. 10. *Mazoniscorpio mazonensis*, gen. et sp. nov. B.U.721A. Chelicerae, carapace, and 1st tergite. $\times 5$. *cc*, coxa of L. chelicera outlined by broken line; *cp*, coxa of L. pedipalp; *et*, eye-tubercle; *fb*, finger of L. chelicera bent backwards; *fd*, fixed finger of R. chelicera; *ff*, free finger, ditto; *fp*, femur of L. pedipalp; *me*, median eye; *mg*, median groove; *pl*, posterior lobe covered with minute granules; *ps*, pleural skin; *R.ch*, right chelicera; *sa*, setae and hair-bases of ant. outer skin; *sm*, short setae of *sa* in Marco; Tvii, tergite of 7th segment.

TEXT-FIG. 11. *Mazoniscorpio mazonensis* gen. et sp. nov. B.U.721C. Pre-anal caudal ring (Cxviii) and poison-capsule (*pc*) and aculeus (*ac*) of the sting. A, In ventral view showing the shield-like surface of Cxviii and the folded ventral surface of the capsule. B, Dorsal aspect with aculeus (broken line) restored to its original position, *dk*, dorsal keel. C, Aculeus in plan and section. D, Sagittal diagram-section of present postures with spaces between the crushed skin opened up. Arrows show direction of crushing pressure. E, Tentative restoration, anus (*an*).

originally appeared as rather wide lines (Pl. 49, fig. 1). They carry, possibly on the doublure, a few small hair-bases. The surface of the tergites is devoid of granules, but have a uniform coating of minute hairs without visible hair-bases, which is similar to that on the front of the carapace. There are folds across the ends of some of the tergites which suggest that in life they were strongly arched from side to side.

Metasoma. Tergal plate xiii. The outer surface of this was completely exposed by the etch. It has the normal outline, rapidly narrowing backwards to about one-third its anterior breadth to accommodate the 1st caudal ring. It carries a pair of strong, knobbly dorsal keels which end well in front of the true posterior margin at points where they meet a transverse ridge that mimics the appearance of the real margin. As a result of having these keels, the tergal plate resembles the dorsal sides of the caudal rings. Assuming that the keels were for muscle attachments, it would appear that the arching of the tail and sting over the body of the 'scorpion' involved the last segment of the abdomen as well as the caudal segments.

Metasoma. Sternal plate of segment XIII is poorly exposed, most of its chitin having been lost or else pressed against the inside of the tergal plate. From what is left in specimen B it appears to have been wider than the latter and to have ended in two postero-lateral processes (Pl. 51, fig. 4).

Caudal rings and sting (Pl. 49, fig. 2; text-fig. 11). Caudal rings XIV-XVII etched out complete as a sort of bridge from the body to the wall of Marco to which CXVII was attached (i.e. the sawcut referred to above). It was not feasible to clear all the matrix from below the bridge, and for that reason they can only here and there be viewed by transmitted light, and details of their ventral sides are unknown. Owing to compression the rings appear wider than they originally were. Each carries a pair of strong dorsal keels (it cannot be seen that these are denticulate) and a pair of lateral or dorso-lateral keels. They all resemble closely the corresponding rings in *Buthiscorpius buthiformis* (text-fig. 2).

The caudal ring of the pre-anal segment XVIII and the sting are preserved in specimen C (text-fig. 11). The caudal ring is short and this may be due to the sawcut that severed it from specimen A, but it appears to be complete. It is not much longer than the preceding ring, and in this respect differs from the corresponding segment in *Buthiscorpius*. As the ring and sting are completely transparent every detail can be examined. The dorsal surface of the ring has two short, posteriorly elevated dorsal keels, but is otherwise devoid of conspicuous features, except for a dark blotching of the skin and two minute longitudinal folds at the distal end (text-fig. 11B). These may have led to a median sinus on the posterior margin, but this, if present, is concealed by the folded sting. The blotching and folds recall features seen in the pre-anal segments in *Mesophonus* (Wills 1947, p. 69, text-fig. 34). The ventral surface in its flattened state is clearly seen to have an almost rectangular shield-like shape that is defined by folds at the front and sides, and by a strong posterior margin and doublure behind. Near this margin were long setae, a few of which are still in place. In addition there are on various parts of the ring several small sensory hairs (one still in place) attached to hair-bases, and many short hairs like those that coat the front of the carapace and the tergites. These latter appear to be on the ventral surface only.

The sting (text-fig. 11) consists of a crushed and crumpled, originally flask-shaped, poison-capsule and a long, strongly curved aculeus. The latter is now broken away from the neck of the capsule, but was seen during development to rise vertically from it (the neck is still visible in this position, but the broken aculeus had to be mounted on its side). As found, the aculeus pointed distally with its concave side ventral. To attain this posture (text-fig. 11D) it must have been inverted during the consolidation of the rock by pressure applied to the whole sting as it stood up almost vertically over the pre-anal ring in the posture usually to be seen in dead scorpions. In the capsule various folds of the skin can be seen, but its exact original shape is hard to determine. Text-fig. 11E shows a possible reconstruction. Some parts of it are closely covered by numerous small hair-bases, often with short setae attached. The aculeus itself (text-fig. 11C) tapers gradually to a fine point. Its smooth, thick chitin is folded longitudinally in a way that strongly suggests that it contained a pair of poison-ducts (as is the case in Recent scorpions and in the Triassic *Mesophonus*. See Wills 1947, p. 75.) Near the base of the broken part of the aculeus is a single tiny hair-base.

Ventral organs

As appears to have been the case in several of the 'scorpions' developed, the original fracture of the nodule followed the inside of the dorsal skin, and where the ventral skin had been closely apposed it suffered some damage. In the present case most of the ventral organs can be seen in specimen B as far back as the last sternite (Sxii), but important parts of them are damaged or missing, so that some uncertainty as to their shapes is inevitable.

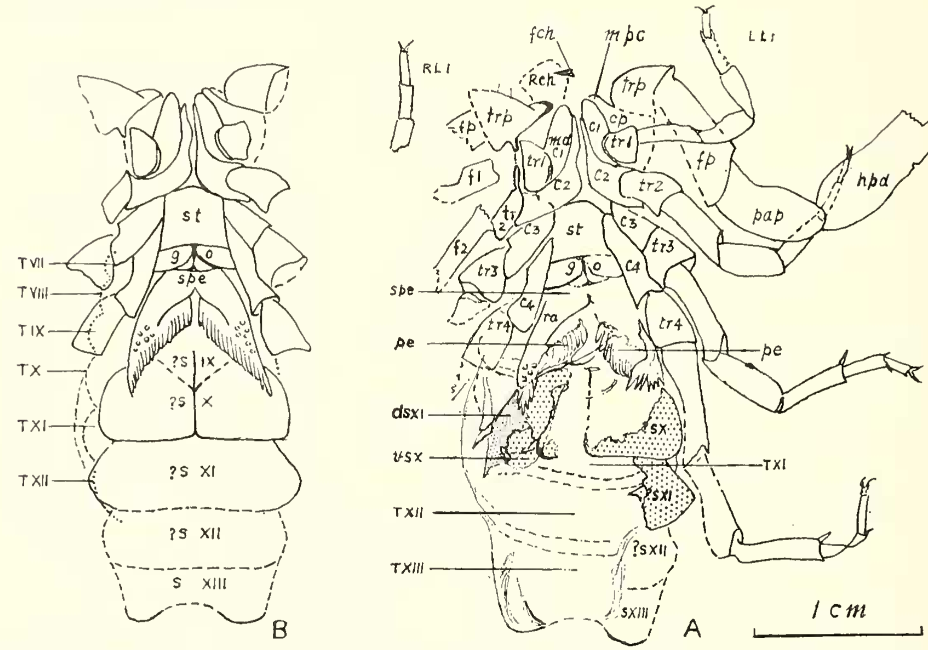
The ventral half as originally exposed in dorsal aspect is shown on Pl. 50, fig. 1. The outlines of parts of the chelicera, of the two pedipalpal trochanters, of the mandibular processes of coxae 1 and 2, the end of the 1st R. leg, and bits of other appendages could be made out, but after development many other features appeared (Pl. 50, fig. 2; Pl. 51, fig. 4; text-fig. 12), most of which are still visible in the Marco-block B.

Prosoma. Chelicerae. These show best in specimen A (Pl. 49, fig. 3; text-fig. 10). The basal joint of the L. chelicera can be seen to lie below the left front corner of the carapace, followed by the hand which appears to have been bent backwards on itself (text-fig. 10). The hand of the R. chelicera shows the distal parts of the fingers, while their tips can be seen in specimen B (it is possible that the tips referred to belong to the L. chelicera). The hands are at least half as long as the carapace (cf. *Lichnophthalmus* in Part 1, p. 288). In specimen B the Marco-block carries many short hairs scattered over the impression of the R. hand, and one or two larger ones on the fingertips.

Pedipalp. The original fracture damaged the coxae and trochanters of the pedipalps, but their general shape can be seen to be quite normal. The distal ends of the coxae carried rather large hairs (? trichobothria) and so did the trochanters which also have a coating of smaller bristles like those on the carapace, tergites, &c. The rest of the appendage consists of massive articles of the normal shape in Recent scorpions. The whole R. hand except the very tips of the fingers is preserved in specimen A, and in B the L. one is complete save for the end of the fixed finger, but bits of the missing part were recovered (Slides A/4, A/6; Pl. 50, fig. 3). The mounts show that there was a row of large granules along the biting edge with a second row of widely spaced still larger ones farther from the edge, a few long, slender, certainly trichobothrial bristles and numerous smaller ones without conspicuous bases, and that the skin was thick and markedly cellular in texture. The femur, patella, and palm of the hand have few or no hairs that can be seen. The patella and hand are crumpled by several large lengthwise folds which imply that in life both were strongly keeled. No 'stop-knob' can be seen on the patella.

These features can be matched in large Recent forms, in *Buthiscorpius major* (Pl. 52, fig. 3), and in *Lichnophthalmus* (Part 1, p. 278, pl. 49, fig. 7). The general shape is also much the same as in *B. buthiformis* (Pl. 47, fig. 3) which, however, is relatively shorter and, perhaps because of its small size, has no granules on the biting edges.

The coxo-sternal region and legs. These only differ in minor points from those of certain Recent Buthids and from the other Carboniferous Orthosternid 'scorpions' here described which show these organs, in particular *B. buthiformis*, B.U.720. The relation of coxae to the sternum is that stated by Petrunkevitch (1955, p. P73) to characterize the superfamily Scorpionoidea Leach 1815, namely—'First and 2nd pairs of coxae with well-developed maxillary lobes (fig. 40, 1), those of the 2nd pair meeting in median line and wedged in between maxillary lobes of 1st pair; 3rd and 4th pairs of coxae abutting against sternum'. His fig. 40, 1 is based on one of Pocock's paratypes of *Buthiscorpius buthiformis* (B.M. In. 1555).



TEXT-FIG. 12. *Mazoniscorpio mazonensis* gen. et sp. nov. BU.721B. A, Ventral view of the ventral organs with the positions of some dorsal elements (broken line), cf. Pl. 50, fig. 2, Pl. 51, fig. 4. B, Tentative restoration of the same, the existence of the plate marked ?Sxii being in doubt. *d*Sxi, internal (dorsal) skin of the pouch above Sx (this skin belonging to Sxi); *fch*, finger of ?R. chelicera; *mpc*, maxillary lobe of coxa of pedipalp; *v*Sx, internal (ventral) skin of the pouch above Sx pressed against the external skin of the same. For key to other abbreviations see p. 277.

The coxo-sternal region and the left legs are well seen in specimen B (Pl. 50, fig. 2; Pl. 51, fig. 4; text-fig. 12).

The *sternum* is pentagonal with its two anterior edges, defined by the back edges of the two coxae 4, making an angle of 130°, and with its posterior edge slightly emarginate where it adjoins the genital operculum. Against its sides abut coxae 3 and 4.

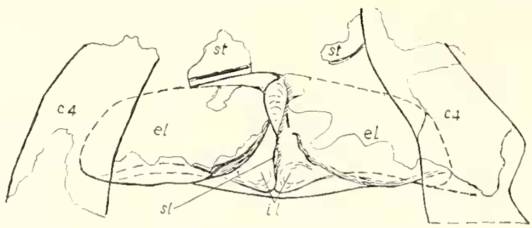
The big coxae of the *pedipalp* appear, in ventral view, to underlie the mandibular processes of coxae 1 and 2. The maxillary process of the L. pedipalp with a few largish hair-bases is well exposed (text-fig. 12, *mpc*). The mandibular processes of the *1st leg* are much broader than those of the *2nd leg* (in Recent scorpions the reverse is the case). Both processes have a felt of minute hairs on the inner sides of their tips. The rest of coxa 1 is small, little more than an articulation for the small trochanter. In contrast the small mandibular processes of coxae 2 pass into large horn-shaped articular ends, the posterior sides of which define the front of the sternum. The coxae of the 3rd and 4th legs abut against the sides of the sternum, that of the 4th leg being about twice as long as that of the 3rd. The two on the L. side seem to be still united, whereas there appears to be a gap between those on the Right. This appearance is probably the result of the loss or fracture of the thin connecting chitin.

The four L. legs are preserved virtually complete in specimen B (Pl. 51, fig. 4), but in specimen A all the R. legs except the 3rd are broken (Pl. 49, fig. 2). In general shape and proportions all are closely similar to the much smaller ones described in *B. buthiformis*, but nearly every joint can be seen to be covered with a felt of small setae comparable with those on the carapace, tergites, &c., and the claws are denticulate, as in all the larger specimens here described. The pads (*Gehstachel*) at the base of the claws are quite small, as in other orthosterni. Spines, sensory hairs, and spurs on the intersegmental skin at the base of the tarsus and metatarsus are conspicuous and arranged as in *B. buthiformis* (p. 289), in particular two tarsal spurs on all four legs, and a single metatarsal spur on the 3rd and 4th. The ends of the four legs were displayed simultaneously at one stage of the etching and were photographed (Pl. 49, figs. 4–7). The figures show that the tarsus gets progressively longer with the increase of length of leg from the 1st to 4th. That on the second appears to be very slender, but this may be due to an accident of preservation. Details of the claws, spurs, spines, and sensory hairs (? small trichobothria) are well shown on the end of the 2nd or 3rd R. leg which broke loose during the etching of specimen A. Mounted as Slide A/3 (Pl. 50, fig. 4) it displays very clearly the spiny ends of the sides and lower surface of the metatarsus, a feature not noticeable in the metatarsus of other specimens, but one that I note below as being conspicuously developed on the tibia of the 3rd leg of G.S.M., Za 2924 (text-fig. 19E). Slide A/3 also makes clear how the pad is connected by prominent ridges to the bases of the claws.

Mesosoma. There is very little ventral skin preserved behind the genital operculum and it is not easy to trace any margins to the sternum of the pecten and the first sternite (S IX). The next two were better preserved, their L. postero-lateral parts having etched out well. I photographed them under water (Pl. 50, fig. 2, Pl. 51, fig. 4) to obtain a record. Then in order to be able to examine them from both sides, and because they appeared to be almost detached by the solution of an underlying (in ventral view) film of matrix, I prised them away without breaking them and mounted them as Slide B/2 (Pl. 51, fig. 5). At the point on the Marco-cast from which the supposed SX was detached, there is an area covered with thin chitin. Somewhat similar, but less distinct patches follow where the next sternite (SXI) was lying and where the supposed last sternite (SXII) is indicated in text-fig. 12. I think that the fragment of sternite mounted as Slide B/1 (Pl. 51, fig. 6) may be the L. end of SXII, derived from above this last patch, but its exact provenance is unknown. If I am right in this interpretation, SXII would in ventral view lie partly over TXII and partly over TXIII, as shown in text-fig. 12. If I am wrong, those segments marked ?S IX–SXI must be in reality SX–SXII, and the part marked ?SXII must be merely the front half of SXIII.

Accepting my preferred interpretation (text-fig. 12) the following features may be noted.

The *genital operculum* (text-fig. 13) is a complex organ, the skin of which is still preserved in slight relief. It is almost oval in outline with the anterior edge making an obtuse, forward-pointing angle. This edge at one point can be seen to be parallel to the posterior margin of the sternum. Both its sides are obscured by the flattened 4th coxae. The posterior edge curves gently backwards near the middle line, is overhung by the external lobes (see below), and is inturned as a narrow doublure. The whole operculum is clearly a bilaterally symmetrical organ consisting of two pairs of lobes, the two external



TEXT-FIG. 13. *Mazoniscorpio mazonensis* gen. et sp. nov. B.U.721B. Parts of the sternum, genital operculum, and the two coxae 4. $\times 10$. *c*4, coxa 4; *el*, external lobe; *il*, internal lobe; *sl*, slit in median ridge; *st*, sternum.

ones (*el*) being arched and falling away towards the posterior margin and towards the two internal lobes (*il*) which are also slightly arched. Down the middle line is a continuous narrow ridge or keel which, towards the front, carries a leaf-shaped flattish structure. Behind this the ridge at one point shows a narrow slit which may represent the opening of the genital duct, but is more probably an accident of fracture.

With this specimen before us it is now clear that the structure in *Lichnophthalmus pulcher* Petr., tentatively interpreted as an anterior plate of the sternum of the pecten (Part 1, p. 272, text-fig. 4), is really the genital operculum, since it also consists of two pairs of lobes with a median ridge. I pointed out the possibility that this might be the case, and noted that, should it turn out to be so, then coxa 4 lay alongside the genital operculum (as is the case here), and did not abut against it as it does in *Pareobuthus*, *Eobuthus*, and other 'Isobuthidae'. See also Addenda, p. 331.

Behind the genital operculum, on the 8th adult segment, the *sternum of the pecten* is poorly defined, but appears to have been short. It carried a pair of large combs on which the raches are very broad at their bases but taper to a point. Possibly both combs have been broken and the teeth displaced backwards near the middle line. The rachis carried, at any rate distally, bosses with sensory hairs (a feature common to all the combs examined); fulcra cannot be recognized but may well exist; sixteen teeth canbe counted on the L. comb.

Behind the sternum of the pecten a long stretch of the ventral skin, partly destroyed and partly covered by the combs, could easily account for two sternites, but I think it was more probably occupied by a single large one (the supposed *sternite IX*), the posterior margin of which was a broad V evidenced by a groove in the Marco. Since the median suture of Sx can be traced across it, the groove may indicate the limit of the area on Sx covered by the V-shaped end of S IX.

Much of the supposed sternite X has survived. It was a roughly rectangular flat lamellate organ with a median division (perhaps in the form of a suture) and a small median posterior notch between the two halves. (It is interesting to note that in *Pareobuthus* sternite X also shows a line of very thin skin between its two lobes, which appears to be absent from the other sternites. Wills 1925, pl. 3, fig. 2.) Much of the L. half was originally seen in place (Pl. 50, fig. 2; Pl. 51, fig. 4), but is now mounted as Slide B/2 (Pl. 51, fig. 5). The R. half had been displaced and crushed sideways, but many of its details can still be seen in the Marco-block (text-fig. 12A), including indications of the median notch.

Only the R. end of the supposed sternite XI was seen during the etching, and this came away attached to the adjacent piece of sternite X (Slide B/2, Pl. 51, fig. 5). As noted above, another end of a sternite was detached by the etching before its position had been noticed. It may be the L. end of sternite XII, but it could equally well be the R. end of sternite XI. Here it is regarded as the L. end of sternite XII (Slide B/1, Pl. 50, fig. 5; Pl. 51, fig. 6). Sternites XI, XII are very badly preserved, and no sign of a median suture can be seen. The absence of chitin is due to the ventral skin having been pressed against the dorsal, and the two having broken away from specimen B. The ventral skin can be seen in places in specimen A, but no details can be made out.

In text-fig. 12A I have shown by broken lines the position of the intersegmental skin between tergites XI, XII, and the tergal plate of segment XIII, and on text-fig. 12B the ends of all the tergites, as in specimen A. From these it will be seen that on the proposed interpretation each sternite covers not only its corresponding tergite, but about half of the next one behind, SXII eventually concealing the front half of SXIII, which last is only represented by a few scraps of chitin, whereas the whole of tergal plate XIII is preserved in specimen A (Pl. 49, fig. 2). Each overlap formed a pouch opening to the sides and behind. Some parts of the overlapping portions of each of the supposed sternites X–XII can be examined—the L. ends as Slides B/1 and B/2 and the R. end of SX in the Marco-block B. In every case they consist of an external layer and a large thin-skinned doublure, and in B/1 and B/2 both surfaces can be seen to be covered closely by a felt of very minute hairs (Pl. 51, fig. 6). At the L. end of SX, a patch of thin chitin can be seen in the Marco-block at the point from which Slide B/2 was detached, and a similar patch shows at the right end where sternite X has been displaced (text-fig. 12A, *d*SXI). These are regarded as the dorsal or inner linings of the pouches, the skin itself being the overlapped portion of the next segment behind. On the same figure the letters *v*SX point to the crumpled and displaced outer skin and doublure of the overlapping SX.

These observations appear to prove that at either end of each sternite the postero-lateral corner concealed a pouch, the ventral lining of which was the posterior doublure of that sternite, and the dorsal lining of which was the anterior part of the next sternite behind (or the sternal plate, SXIII, in the case of the last one). In this respect the sternites compare exactly with the leaf-appendages (*Blattfüsse*) of *Eurypterus*, but the overlap being relatively narrower they had less freedom of movement, and were correspondingly more like true sternites than leaf-appendages. The general arrangement also matches closely the structure of the sternites in *Pareobuthus* (Wills 1925) and *Lichnophthalmus* (Part 1, p. 274), though the sternites in the present case are not bilobate, and have hairs instead of spinelets on the doublure.

Imagine a gill within each pouch and we have a structure comparable with that of a *Blattfuss* of *Eurypterus fischeri* Eichw. as described by Holm 1898. The available space for the gill, however, would seem to be relatively much smaller than in *Eurypterus*, and the sternites ill-adapted to promote a circulation of water through the gills. Such an interpretation would nevertheless seem to imply a truly aquatic life for this particular Orthostern 'scorpion', an environment similar to that inferred for the Lobosterni described in Part 1.

Alternatively, imagine some air-breathing organ, perhaps a lamellate structure akin to a gill-book, occupying the pouches and protected from drying up by the close-fitting, hair-covered corners of the 'sternite', and we have an arrangement that can be pictured as a first stage in the evolution of a scorpion's lung-books. By the fusion of the outer edge of the first sternite to the overlying 'sternite', except for a short strip at either end, the arrangement found in the Triassic *Mesophonus* could follow. Here the lung-book opening (stigma) is either on the postero-lateral margin or on the adjacent doublure that connected that sternite to the next one behind (Wills 1947). Starting again from that arrangement, it is easy to postulate a simple migration of the stigma from the edge to the outer surface of the sternite to account for the siting of the pulmonary opening in present-day scorpions.

On this second hypothesis this particular Orthostern 'scorpion' would rank as an air-breather, though probably only adapted to life in a moist environment.

There is no satisfactory evidence as to which hypothesis is correct, but the amount of overlap in the present case is greater than in *B. buthiformis*, and large enough to make me favour the aquatic one.

SECTION B—ONLY HALF-NODULES AVAILABLE

Buthiscorpius major sp. nov.

Plate 51, figs. 1–3, Plate 52; text-figs. 14–16

Holotype. G.S.M. Za 2926. Coal Measures (Ammanian), base of *Communis* Zone, Kilburn Coal, Trowell Colliery, Nottinghamshire.

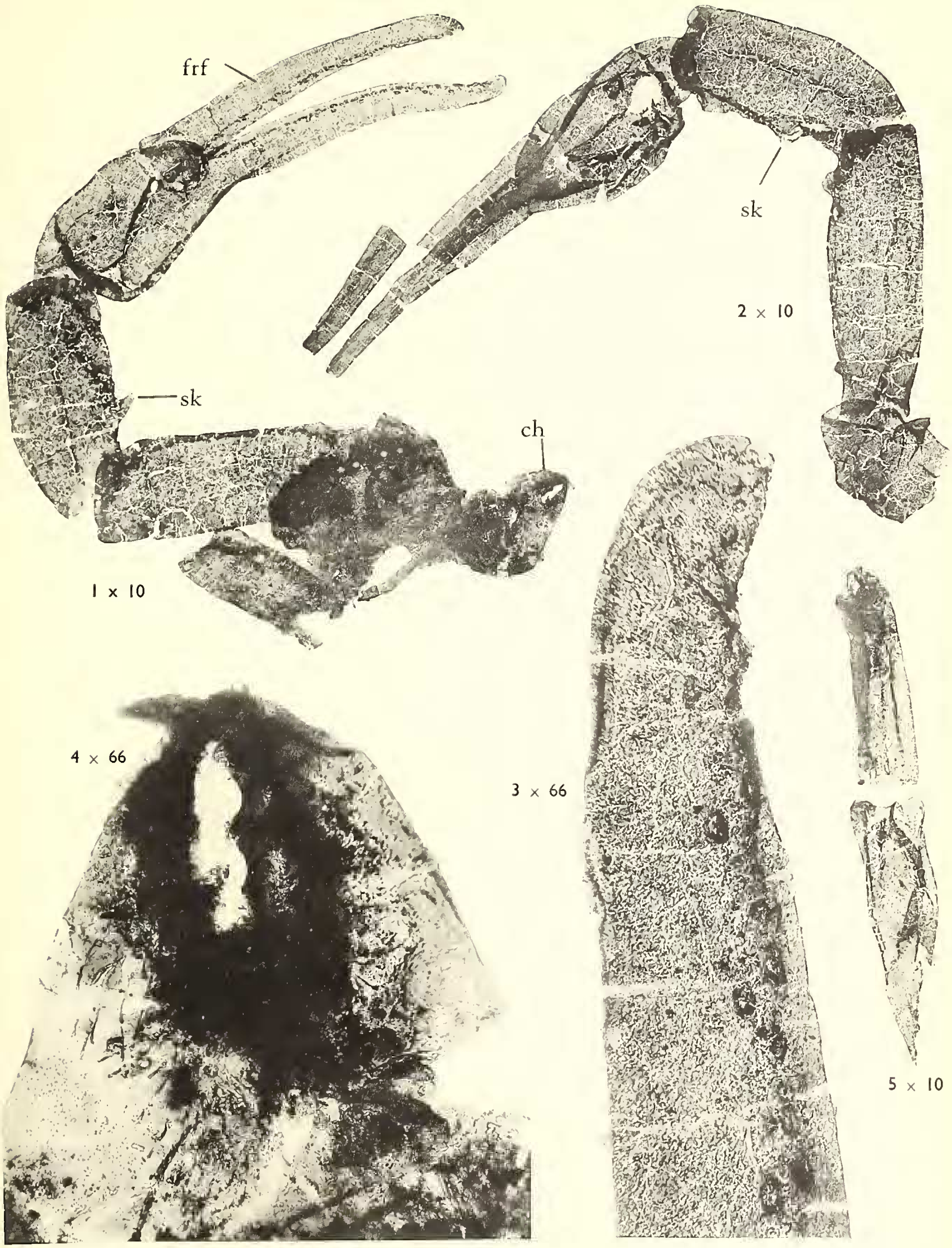
Remarks. As originally exposed, there were visible most of the carapace, the mesosomatic tergites, the tergal plate of the 13th segment, all the caudal segments of the metasoma except the sting, and several bits of the legs (Pl. 51, fig. 1). After photography the specimen was embedded in Marco, but during the grinding away of some unwanted matrix, the Marco-mount cracked right across, and a fresh start had to be made. In trying to extract the nodule from the cracked mount the specimen was broken in two, but *not at the place* where the mount had split (Pl. 51, fig. 3). The rock containing the tail adhered to the Marco, and was later developed by solution. This first mount with its cracks repaired provides a record, in the form of a cast, of what was originally visible and also of what was etched out in the caudal region. It is referred to in the sequel as the *1st Marco-cast*.

The part of the nodule which broke away from this first mount contained the body and appendages. It was remounted and developed by solution, and after several parts of the scorpion had been extracted, the second mount remained as the *2nd Marco-cast*. Parts of the sting and of one leg, however, were

EXPLANATION OF PLATE 52

Figs. 1–5. *Buthiscorpius major* sp. nov., G.S.M. Za 2926. 1, L. chelicera and pedipalp minus its coxa, in dorsal view. Slide Za 2926/1. ×10. 2, R. pedipalp minus its coxa in dorsal view, except the broken end of free finger which was inverted in mounting. Slide Za 2926/2. ×10. 3, Tip of the free finger of L. pedipalp in ventral view. Slide Za 2926/1. × 66. 4, Hand of the L. chelicera in ventral view. Slide Za 2926/1. ×66. 5, Coxa (below) and trochanter of ?3rd or 4th R. leg. Slide Za 2926/3. ×10.

For key to abbreviations see p. 277.



WILLS, *Buthiscorpius*

left attached to it in their original positions and can still be seen in place (Pl. 51, fig. 2). It was surprising to find the sting on this Marco-cast as the rest of the tail was etched out on the 1st Marco-cast. It must have been bent back over the tail since the aculeus points towards the head of the scorpion.

At first it was assumed that the visible dorsal organs were exposed in dorsal aspect on the half-nodule, but on development it was found that in fact they were exposed in ventral view, for the 2nd Marco-cast has the eye tubercle projecting upwards and the tergites overlapping one another backwards as ridges (see text-fig. 14 and Pl. 51, fig. 2). This explained the disappointing fact that the ventral parts—the sternum, genital operculum, pecten, and sternites—were not discovered during development. They lay in the other half-nodule which had not been collected. However, one chelicera, both pedipalps, and the coxa and trochanter of the 3rd or 4th right leg were isolated with the original brown chitin virtually free from matrix. Their most intimate details of structure can be examined in transmitted light (Pl. 52), and it can be demonstrated that these parts were organized in Carboniferous times on almost exactly the same lines as they are in a Recent buthid scorpion.

B. major is undoubtedly an Eoscorpioniid comparable with *Eoscorpius* Meek and Worthen, *Buthiscorpius* Petr., and *Compsoscorpius* Petr. The carapace of the holotype of *E. carbonarius* lacks its front half, and so comparison with it in respect of the shape and proportions of the carapace, and the position and nature of the eyes is precluded. I thought at one time the present specimen showed one or more lateral eyes, but am now convinced that I was mistaken. Had lateral eyes been present the specimen could be ascribed with assurance to *Compsoscorpius elongatus* Petr.; but as they are not, comparison is closest with *Buthiscorpius buthiformis* Pocock, as described above, though the median eyes appear to be almost touching one another instead of being separated by ridges as they are in that species (text-fig. 1). The preservation, however, is too poor for certainty on this point. The fossil is, however, almost twice the size of the holotype of *B. buthiformis* and considerably larger than any of the specimens attributed to that species by Pocock or by me. For convenience in description and reference I name G.S.M. Za 2926 *Buthiscorpius major* sp. nov.

Diagnosis. Large Eoscorpionid 'scorpion', about twice the size of *Buthiscorpius buthiformis* Pocock; carapace ornamented with granules, some being large, mimicking lateral eyes which are absent; median eyes small and near to one another on an eye-tubercle without visible ridges between the eyes; eye tubercle about two-fifths of carapace length from the front; tergites with mucronate posterior margins; tail short and relatively shorter than in *B. buthiformis*; caudal ring XVIII not much longer than the previous one, and shorter than the flask-shaped sting. Pedipalp hand with fingers longer in proportion to the palm than in *B. buthiformis.*

Dimensions. The holotype lay squashed almost flat on the ironstone. For purposes of comparison of its dimensions with those of *B. buthiformis* Pocock as described above, it must be recognized that the tergites of the present specimen are telescoped from back to front and flattened, so that the length-dimensions are relatively less and the breadth-figures relatively greater than corresponding measurements in the Birmingham specimen which was fully distended lengthwise and strongly arched from side to side; and that both the above-described specimens are larger than the holotype of *B. buthiformis* which (without the sting) is only 22 mm. long. Making allowances for differences in preservation and for possible differences in age of the individuals, I consider it probable that the present specimen represents an adult of a species that was about twice the size of *B. buthiformis*. Hence the specific name *major* is proposed.

Approximate dimensions in mm. Carapace, length, 7–8; width, ? 7. Abdomen, length, 12; width (maximum at Tx), 8·5; width of TXIII at front, *c.* 7, at back, *c.* 3·5. Tail, length CXIV to CXVIII, 13; width (crushed), *c.* 3. Sting, *c.* 6. Total length, 38–40. Chelicera (hand), 2. Pedipalp, trochanter, 2; femur, 4·5; patella, 4; palm of hand, 3·5; fingers, 4·5; total length (excluding coxa), 18·5.

Description. The body

Carapace. Pl. 51, figs. 2, 3, text-fig. 14. The exact outline of the carapace is difficult to make out, the sides being in places distorted or broken away. It is best seen in the 1st

Marco-cast. It was probably almost as wide as long if allowance be made for arching, with rounded antero-lateral corners and the anterior side slightly emarginate, but it is possible that there was a median anterior triangular process, but if so it is now broken and distorted. Probably the carapace sloped sharply downwards at the front and sides. The median eyes are represented by one well preserved on the right and the other crushed. They are situated, at about one-third of the carapace-length from the front,

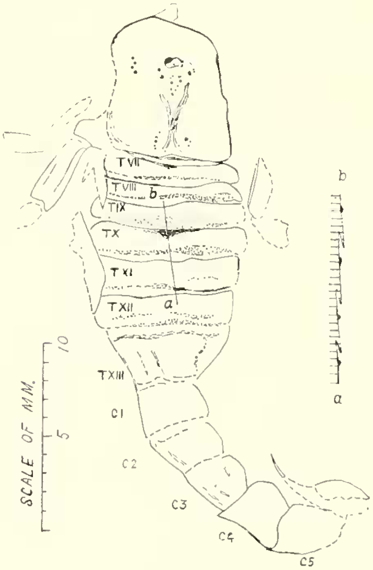


FIG. 14

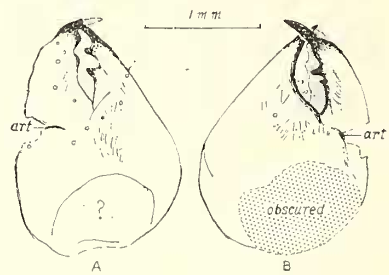


FIG. 15

TEXT-FIG. 14. *Buthiscorpius major* sp. nov. G.S.M. Za 2926. Dorsal view of dorsal surface as now visible in the two Marco-casts, with a diagram section along line *ab* to show the cast of the inside of the overlapping tergites. For key to abbreviations see p. 277.

TEXT-FIG. 15. *Buthiscorpius major* sp. nov. G.S.M. Za 2926/1. Details of L. chelicera; A, in dorsal; B, in ventral view. *art*, articulation, ? trichobothria shown as rings.

on a slight eye-tubercle, on the hinder side of which are several large granules. The tubercle drops away behind into a forwardly bifurcating median groove flanked by two ridges which also bear granules. On the left, half-way between the eye-tubercle and the lateral margin, is a group of four or five larger granules in the form of knobs in the Marco which might be mistaken for lateral ocelli were they in the usual position. Other rather smaller knobs also occur on the antero-lateral margin. None of the knobs, however, are large enough or round enough to warrant the assumption that they are lateral eyes; for we have casts of true ones for comparison in *Compsoscorpius elongatus* Petr. (B.M. I.15862, figured by Petrunkevitch 1949, figs. 148, 150).

Mesosomatic tergites. Pl. 51, figs. 1–3, text-fig. 14. The general shape of the tergites is that normally found in Carboniferous 'scorpions', as fully described on p. 320. Hardly any of the chitin has survived the etching, but Pl. 51, fig. 1, shows by dark patches that it had been broken into a mosaic, as in *Lichnophthalmus* (Part 1, p. 270). There was little ornamentation except for some flat mucronate tubercles of dark-brown colour along the posterior margins which are best seen in Pl. 51, fig. 3. Each tergite is defined by a slender linear margin at the front and sides, and by a sharp infold (doublure) behind, which can best be seen on Txi in the 2nd Marco-cast (fig. 2). The arrangement is illustrated by the section AB on text-fig. 14. In Tvii–Tix there is a median depression just behind the anterior margin (as there is in many Recent forms). The tergites are connected to the head in front, to the tergal plate xiii behind, and to one another by strips of intersegmental skin that appear rather narrow because of the partial telescoping of the segments. It will be recalled that the corresponding strips are fully exposed in the Birmingham specimen of *B. buthiformis* which accounts for quite a considerable increase in its length (p. 286; see also p. 320). Bits of the pleural skin connecting tergites to sternites and showing the linear margins are mounted on Slides Za 2926/8–/11.

Metasomatic segments. Pl. 51, figs. 1–3; text-fig. 14. The tergal plate of the 1st metasomatic segment (Txiii) is imperfectly preserved, but appears to have been of the normal tapering shape. Two slight ridges may represent dorsal keels on either side of the midline, but they are much less prominent than those on *B. buthiformis* (Pl. 46, fig. 2).

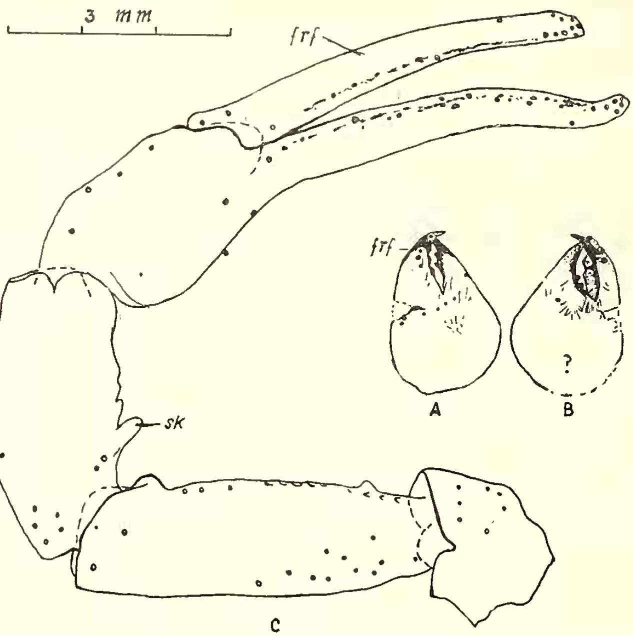
The caudal rings of the tail (Cxiv–xviii) appear unusually broad in relation to their length as a result of flattening and perhaps because the tail seems to have been more or less turned on to its side. Some show longitudinal ridges, but little detail can be made out, even where the chitin has been exposed by the etching (in 1st Marco-cast, Pl. 51, fig. 3). The last ring may be imperfect, but appears to have been not much longer than the preceding one and in this differs considerably from its opposite number in *B. buthiformis*.

The sting was long and curved, but only the actual aculeus and a posterior portion of the poison-capsule lay in the piece of rock that had been collected. These bits have been left attached to the 2nd Marco-cast just as they emerged from the etching (Pl. 51, fig. 2). In text-fig. 14 the sting is indicated in the position it occupied relative to the last caudal ring as was determined from a comparison of the two Marco-casts.

The appendages

Chelicerae. Pl. 52, figs. 1, 4; text-figs. 14, 15. The hand of the left chelicera is preserved intact on Slide Za 2926/1 and the broken coxal joint and bits of the right hand are probably present in Slide /2. The left hand is *c.* 2 mm. long and 1 mm. wide in the crushed state. The fixed finger bears two prominent teeth on one of the two biting edges which in life converged from the broad base of the finger to its apex. The free finger is bifid, the two branches closing one on either side of the fixed finger, and each carrying two flattish teeth. The whole structure must have functioned as a perfect crusher, and as such has been handed down unaltered to many genera of Recent scorpions. (I have found that the free finger is bifid in all the Recent scorpions which I have examined, but I have never seen this character mentioned in descriptions or diagnoses or shown in illustrations.) In Carboniferous times, as today, the chelicerae not only crushed, but helped to strain off any solid particles as the juices were sucked in, as is evidenced by a conspicuous group of small setae on the sides and bases of the fingers (Pl. 52, fig. 4). There were also a few sensory bristles attached to prominent, but small, hair-bases, two of the latter being visible in the photograph (*tri*). See also text-fig. 15. Recent scorpions retain the same general equipment of hairs and bristles.

Pedipalps. Pl. 52, figs. 1–3, text-fig. 16. The two pedipalps were extracted whole and free of matrix (Slides Za 2926/1 and /2). They lie neatly flattened, but curved as in life, with the movable finger on the outside. Neither show the coxal joint, though possibly this forms part of the opaque debris that covers the trochanter and base of femur in Slide /1 (Pl. 52, fig. 1), but this is very obscure. The trochanter is short and wide; the femur has two small knobs on its inner side and displays numerous small hair-bases; the patella (tibia) is longer, with a large 'stop-knob' on its inner side (this is a conspicuous feature in many Recent scorpions), and has a few small hair-bases at its proximal end. Both femur and patella have tuberculated ribs from which the knobs project.



TEXT-FIG. 16. *Buthiscorpius major* sp. nov. G.S.M. Za 2926/1. L. chelicera and pedipalp drawn to same scale (cf. Pl. 52, fig. 1) showing distribution of granules (solid dots) and hair-bases (rings), some being ? trichobothria. The sketch does not differentiate between features on either side of the flattened skin. For key to abbreviations see p. 277.

The hand is long and slender, and nearly half the length of the whole limb (excluding the coxa). The free finger is rather more than half the total length of the hand, is not hooked at the end, and is a little shorter than the hooked fixed finger, if we measure from the apex of the angle between them. There is a conspicuous thickened process at the articulation. The biting edges are each marked by a continuous single row of granules with a number of isolated larger granules at intervals to the side of the main row. These are easily seen on the fixed finger (Pl. 52, figs. 1, 3; text-fig. 16), but I think they also occur on the free finger which has been crushed somewhat. For Recent scorpions the arrangement of granules on the pedipalp fingers is used in classification. The arrangement in Za 2926 can be closely matched with that characteristic of the Buthid genus *Anomalobuthus*, the Vejovid genera *Vejovis* and *Hadrurus*, and less closely with the Bothriurid genus *Jophorus* (see Werner 1934, Abb. 341, 360, 361, 382).

On the great pincers there are also a few hair-bases which are almost certainly trichobothria scattered on the palm of the hand and at the base and tip of the fingers. Their apparent distribution is shown on text-fig. 16, but it must be recalled that it is not easy to discriminate between organs on the two surfaces of the transparent tubular hand in its flattened state. At the tip of the fingers there are also a number of smaller hair-bases which may have carried ordinary small setae. The distribution and type of hair were evidently much the same as in *Mazoniscorpio* in which the actual hairs can still be seen in place on the fragments of pedipalp mounted as B.U.721A/4, /6 (Pl. 50, fig. 3).

The general shape and proportions of the articles composing the pedipalps are similar to those figured in outline by various authors for the following genera *Eoscorpius*, *Buthiscorpius*, *Compsoscorpius*, *Alloscorpius*, *Europhthalmus*, *Eoctonus*, and *Buthiscorpius* and *Mazoniscorpio* as figured here; but the fingers are longer in proportion to the palm than in *B. buthiformis*, and much longer than in *M. mazonensis*.

Legs. Some fragments of legs isolated by solution were mounted as Slides Za 2926/3–/7 and one bit was left in place on the 2nd Marco-cast. Most of the leg joints, however, lie in the other half of the nodule which was not collected. The fragments show distinct keels or ribs, and some have a number of granules and hair-bases; but all are of little interest since they cannot be related to particular legs, with the possible exception of the two joints on Slide /3 which appears to be the coxa and trochanter of the 3rd right leg (Pl. 52, fig. 5).

Unidentifiable 'scorpion', G.S.M. Za 2924

Plates 53, 54; text-figs. 17–19

Remarks. This is labelled '? Scorpio, ? Shipley Clay Pit'. The horizon in the Ammanian Coal Measures from which it is said to come lies below the Top Hard Coal in the Shipley Clay Pit, near Ilkeston, Derbyshire.

Owing to the absence or imperfect preservation of all the diagnostic parts, it is not possible to make even a generic identification of this fossil, but the sternites are not markedly lobed, and for this reason it falls into Pocock's group Orthosterni.

G.S.M. Za 2924 is the much distorted, crumpled, and partly dismembered remains of a large scorpion (Pl. 53, fig. 1). The length of the body, without the tail, and in its broken and crushed condition, is about 20 mm., and the maximum width about 8 mm.; but I consider that originally the body length was probably 27–30 mm. If this is correct—and my view is borne out by the very large size of the appendages—the animal was half as big again as *Buthiscorpius major*. It has been preserved with an infilling or reinforcement of kaolin plus a good deal of crystalline iron pyrites on and inside many of the organs. As a result, some of the leg segments retain their original uncrushed shape with claws and hairs standing out in life-like menacing attitudes (Pl. 54, figs. 4, 5), others have one joint bent sharply back on the next (Pl. 54, fig. 8), while the pecten still displays its individual teeth flexed from the plane of the rachis (like the barbs of an ostrich feather) and arranged *en echelon* along it (Pl. 54, figs. 1–3). Lying across the scorpion were a number of twigs of *Asterophyllites*, also preserved uncrushed and retaining their original shapes by reason of a kaolin infilling of the pith-cavities on the outside of which is a mere film of coaly material (Pl. 54, fig. 1). All these factors and the large size contributed greatly to the difficulty of extraction and mounting. In all, thirty-two separate mounts were made; but the majority consist of fragments, the positions of which on the body are unknown or only known in a general way.

Owing to the flexed posture of the appendages and to distortion of the body almost every part of the skeleton had been broken through when the nodule had been split open. Most of the left pedipalp, except the hand, lay exposed (Pl. 53, fig. 1), but during etching the only appendage extracted in anything like its entirety was the comb of the pecten which was found completely detached from the body, and with the end of the ? 2nd L. leg lying across it (Pl. 54, figs. 2, 3). As solution of the matrix proceeded, various pieces of the legs appeared and were recovered, but it was almost impossible to relate them to pieces lying at other levels. Pl. 53, fig. 2, and text-fig. 18A–C show the general shape and relative positions of the fragments at three stages and as finally interpreted. I would have been well advised to cease the development at the stage shown in the progress photograph, Pl. 53, fig. 2, but I decided to try to mount all parts in order to be able to examine them more easily and, where possible, by transmitted light or from both sides. Unfortunately, while trying to perfect the preparation containing the three sternites that are shown on the progress photograph, I dropped it. The bits that I rescued and mounted are useless. 'Striving to better, oft we mar what's well.'

There are two Marco-casts of Za 2924. The first was the outcome of the failure of the liquid plastic to adhere to the exposed surface of the fossil. The nodule was freed from this mount (first Marco-cast), and a fresh start was made. The second Marco-cast shows what was revealed after etching away the nodule, but a good deal of the chitin that had originally been exposed on the specimen had adhered to the first Marco-cast which therefore gives, on the whole, a better record of what was originally observable.

Description. Dorsal surface of Prosoma and Mesosoma

Carapace. Only about one-third of this was preserved, and since the fracture ran diagonally from the right antero-lateral almost to the left postero-lateral corner, no eyes or eye-tubercle can be seen. The margin and bordering intersegmental skin are well displayed.

Tergites. As originally exposed (Pl. 53, fig. 1) it was difficult to define the number and dimensions of the tergites, some of which, particularly TVIII and TIX, were badly twisted into a sort of hump (text-fig. 17, H). After development, however, the second Marco-cast shows six tergites increasing slightly in length from TVII to TIX, and then becoming considerably longer (as is normally the case). Part of the difficulty of interpretation appears to arise from a distension of the body, which has drawn out the usually infolded intersegmental skin (*isk* on text-fig. 17). This effect can be seen particularly well in front of

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EXPLANATION OF PLATE 53

Figs. 1–3. 'Scorpion', *indet.*, G.S.M. Za 2924. Dorsal aspect, as received; photographed under alcohol. ×3. 2, The same after etching, in ventral view, photographed under water. Impression of pedipalp on Marco-cast outlined. ×4·3. 3, Fragment of a tergite of the same. Slide Za 2924/32. ×86.

Fig. 4. 'Scorpion', *indet.* ? Metatarsus with two large spines, tibia and part of patella of ? 1st R. leg (cf. text-fig. 25). M.M. Slide L. 8194/2. ×46.

Fig. 5. '*Glyptoscorpius*', Calciferous Sandstone, Cementstone Group, Newton Farm, Foulden, Berwicks. B.M. In.25982. Structureless skin of a barbed tooth or filament on a comb which exactly matches Peach's pl. 29, fig. 17 in *Trans. Roy. Soc. Edinburgh*, vol. 30, p. 188. The irregular pattern is due to bits of adherent matrix. ×165.

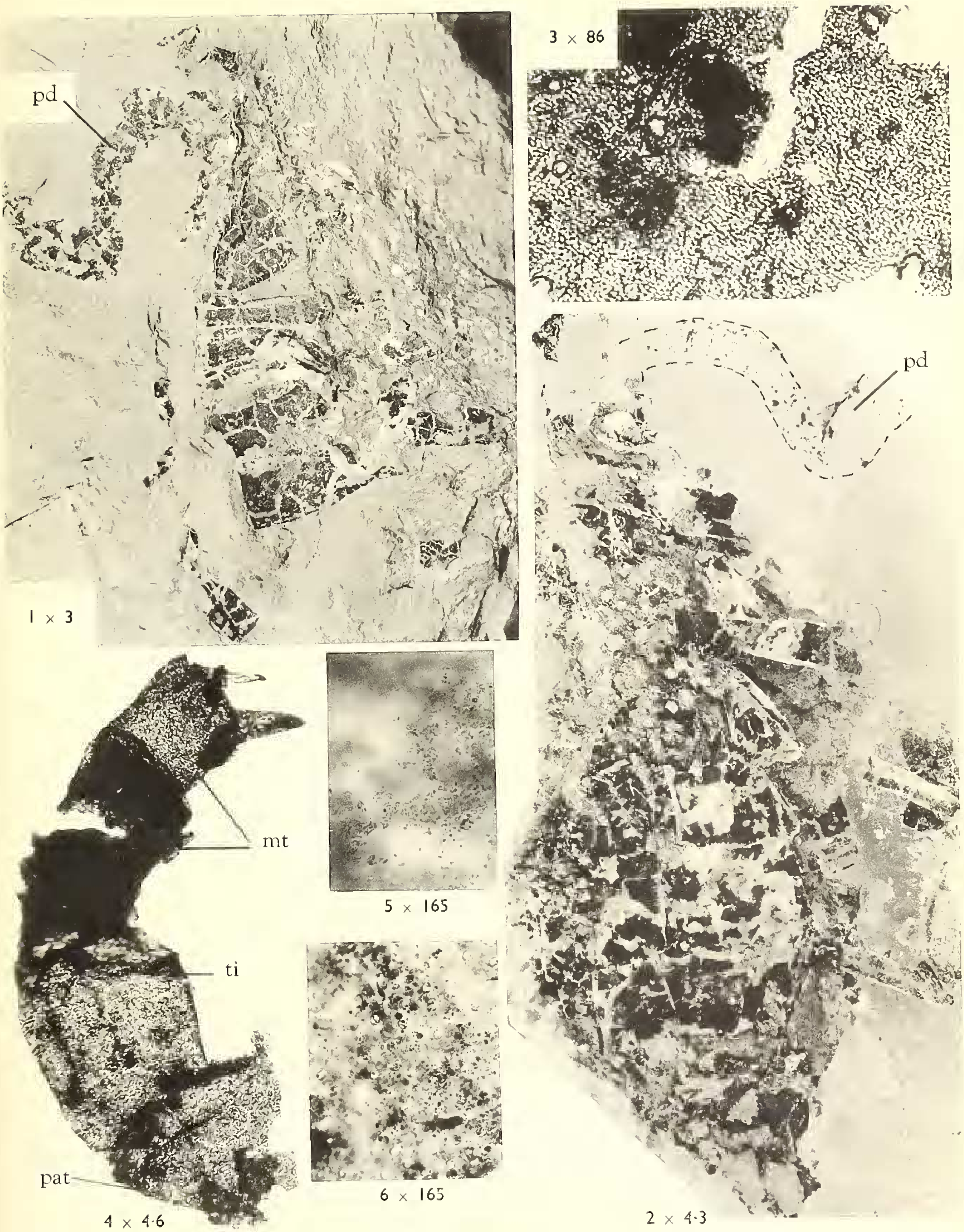
Fig. 6. '*Glyptoscorpius*', Calciferous Sandstone, Glencartholm, Dumfriesshire. B.M. In.42706. Peg-organs on an unbarbed tooth or filament of the comb. ×165.

For key to abbreviations see p. 277.

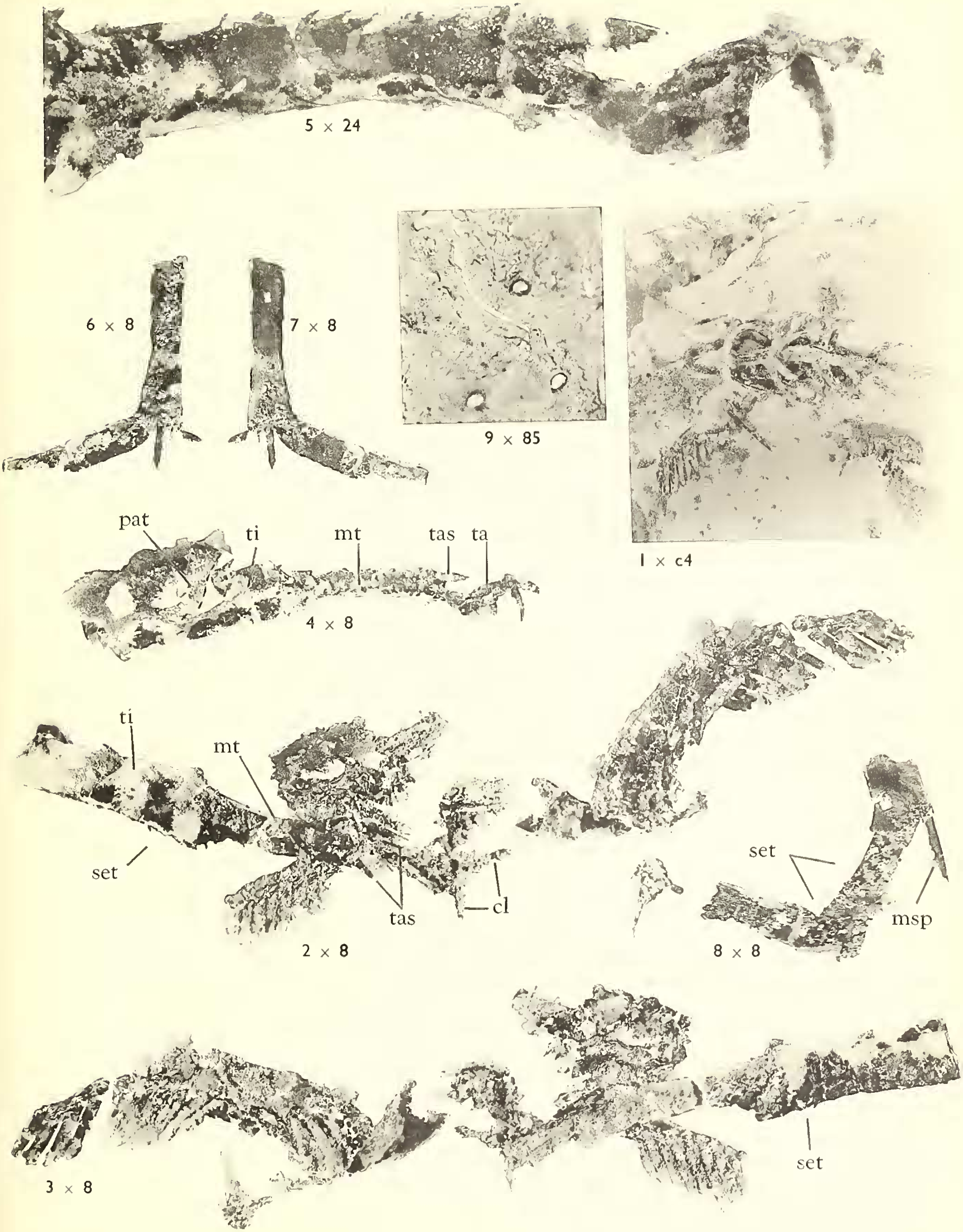
EXPLANATION OF PLATE 54

Figs. 1–9. 'Scorpion', *indet.*, G.S.M. Za 2924. 1, The ends of the two combs in ventral view, partially etched, with twigs of *Asterophyllites* lying across them. ×*c.* 4. 2, End of ? 2nd L. leg with two tarsal spurs and setae, lying across and below the crumpled L. comb; and the R. comb with a displaced tooth. Dorsal view. Slides Za 2924/1, /2. ×8. 3, Ditto, in ventral view. ×8. 4, End of 1st L. leg with the sharply flexed patella concealing part of the tibia. Slide Za 2924/6. ×8. 5, The distal part of the same to show spines on metatarsus and denticulation of the tarsal spur and claws. ×24. 6, 7, The two sides of tarsus and metatarsus of 4th L. leg with tarsal spurs. Slide Za 2924/3. ×8. 8, The tarsus, metatarsus, and part of tibia with large metatarsal spur, ? L. leg 3. The tarsal spurs not shown in this view. Slide Za 2924/4. ×8. 9, Structureless part of the chitin of a tergite with very minute hair-bases. Slide Za 2924/11. ×85.

For key to abbreviations see p. 277.

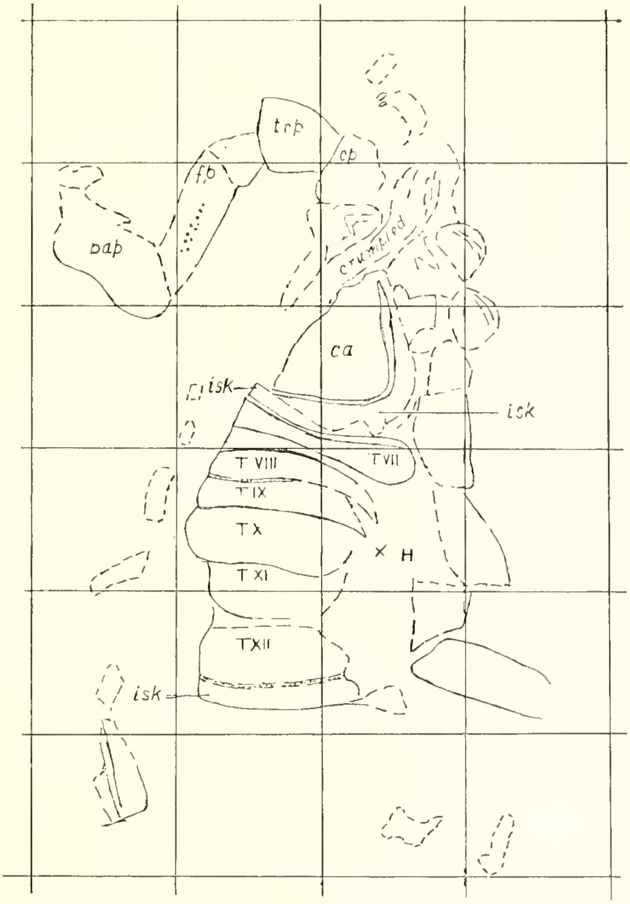


WILLS, indet. 'scorpions' and '*Glyptoscorpius*'



WILLS, indet. 'scorpion'

Tvii and behind Txii. The latter gives the semblance of an additional tergite (see p. 321). In Slide 31 a fragment of the posterior part of a tergite with its border (doublure) of intersegmental skin is preserved in full relief which shows the outer surface and doublure joining at an angle of nearly 90°.

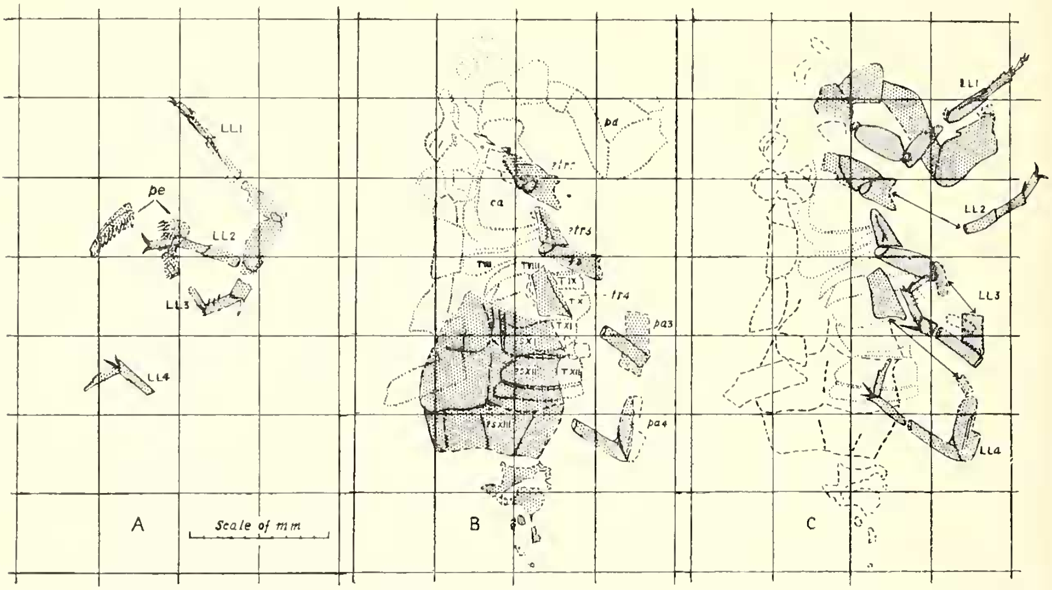


TEXT-FIG. 17. G.S.M. Za 2924. Outline of parts originally exposed or revealed on Marco-cast after etching. Grid of $\frac{1}{4}$-inch squares as on text-fig. 18. H, apex of the 'hump' of crushed tergites; *isk*, inter-segmental skin. For key to other abbreviations see p. 277.

The chitin of the tergites is well preserved in places, and a fragment mounted as Slide 32, Pl. 53, fig. 3, shows a few hair-bases on a dark-brown sheet having a distinctly cellular texture which is closely comparable with the 'reticulate structure' of a tergite of *Pareobuthus salopiensis* (Wills 1925, pl. 3, fig. 17), and of *Lichnophthalmus pulcher* (Part 1, p. 271). Elsewhere, however, bits of a very thin yellow-brown material (perhaps inter-segmental skin or possibly an outer surface-film of the chitin) has adhered to the Marco-casts, which, apart from a few minute hair-bases, appears to be quite structureless (Slide 11, Pl. 54, fig. 9).

Ventral surface of Mesosoma and segment XIII

The only parts of the ventral body-skin recognized were the two sternites and ? ventral plate of segment XIII to whose unlucky fate reference has already been made, and some scraps of one or two caudal segments (Slide 18), of which nothing can be deciphered with certainty. The three ventral body-plates were fairly well exposed at one stage in the development (Pl. 53, fig. 2; text-fig. 18B). At the time I formed the opinion that they



TEXT-FIG. 18. G.S.M. Za 2924. Stages in etching from the ventral side. Same grid as in text-fig. 17. A, Early stage with the combs and distal articles of the L. legs exposed. B, Final stage with ? sternites XI, XII, and sternal plate XIII, proximal parts of three legs, and patella and tibia of two. Dorsal features dotted in. C, Reconstruction. L. appendages with distal parts restored to the proximal ones; alternate appendages with fine and course stipple. Broken lines, ventral sclerites and R. leg fragments; dotted lines, dorsal sclerites. For key to abbreviations see p. 277.

were sternites X, XI, XII, but judging from their position, as now known, in relation to the tergites (indicated on text-fig. 18B), they would appear (unless they had been displaced backwards during fossilization) to be sternites XI and XII and the ventral plate of segment XIII. Towards the middle of each plate the posterior margin appeared to be slightly notched, and the skin was folded in such a way that the development photo (Pl. 53, fig. 2) gives the impression of a median suture comparable with that on sternite X in *Pareobuthus salopiensis* (Wills 1925, fig. 2 and pl. 3, fig. 2) and *Mazoniscorpio mazonensis* (Pl. 50, fig. 2). I made a note at the time that the L. half (right in photo) of the foremost sternite was a double structure or folded on itself. Owing to the loss of the preparation all that can be stated with certainty is that none of the posterior margins were strongly lobed, but gently emarginate, that each overlapped the next one behind by an infold of the intersegmental skin, and that no stigmata occurred on the outer surface of the sternites themselves. Nothing that was seen would rule out the possibility that there were stigmata on the marginal bend-over or on the intersegmental bordering skin or doublure at the postero-lateral corners as in the Triassic scorpion *Mesophonus* (Wills

1947). On the other hand, comparison with *Mazoniscorpio* appears to be so close that the two animals may well have had the same type of breathing organ.

The appendages

As the coxae (except that of the pedipalp), the sternum, and the genital operculum are missing, the relations of the appendages (including the pecten) to the body cannot be stated. Those of the right side are too poorly preserved to be identified: those of the left side appear to have been detached during burial, but without much displacement. It proved difficult to trace the connexions between the distal joints of the legs which were revealed and isolated during the early stages of etching and the proximal joints lying at lower levels. It is now clear that in most cases the intermediate joints lay in the counterpart, which was not collected. In text-fig. 18A, B, the joints of the appendages exposed at two stages of etching are shown in approximately the correct positions in relation to a common grid, and in B in relation to the dorsal organs and the left pedipalp. Text-fig. 18C is an attempted reconstruction of the L. side, with alternate appendages lightly and heavily stippled.

The *chelicerae* were very obscurely exposed and nothing was discovered about them during development.

The left *pedipalp* with the exception of most of the hand was exposed on the original surface in poor preservation, and etching revealed nothing further except strong granules on the femur. The appendage was a powerful one with the relative sizes of the joints much the same as in *Mazoniscorpio* and *Buthiscorpius major*.

The legs. Parts of all four left legs were isolated and mounted. They are almost uncrushed and in several cases have the joints sharply folded, one on the next, in the natural flexed postures of death. In many cases keels, spines, spurs, claws, and bristles project in their original shapes and positions (Pl. 54, figs. 4–8; text-figs. 18, 19B–E). One cannot fail to notice the resemblance of the fossils to the legs of dried specimens of large Recent scorpions, which is so close that it is almost unbelievable that this particular Carboniferous one was not a terrestrial animal adapted to the same general habits as its present-day descendants.

The general layout of the legs when the various parts are restored to their original positions (text-fig. 18C) appears to have been the same as in *Buthiscorpius* and *Mazoniscorpio*, namely, the anterior legs were much shorter than the posterior ones; each ended in a double claw with a pad, and each leg probably carried two tarsal spurs: the 3rd (and probably the 4th) leg had a large metatarsal spur. In addition the trochanters can be seen to have been almost pyramidal in shape (Slide 19), the tibias in some cases were ribbed and spiny, and those of the 3rd and 4th legs were very spiny at their distal ends (Slide 4, Pl. 54, fig. 8; text-fig. 19E). Several other articles also show that they too were strongly ribbed, often with short spines. The distribution of hair-bases indicates that many parts carried bristles, a number of which are preserved.

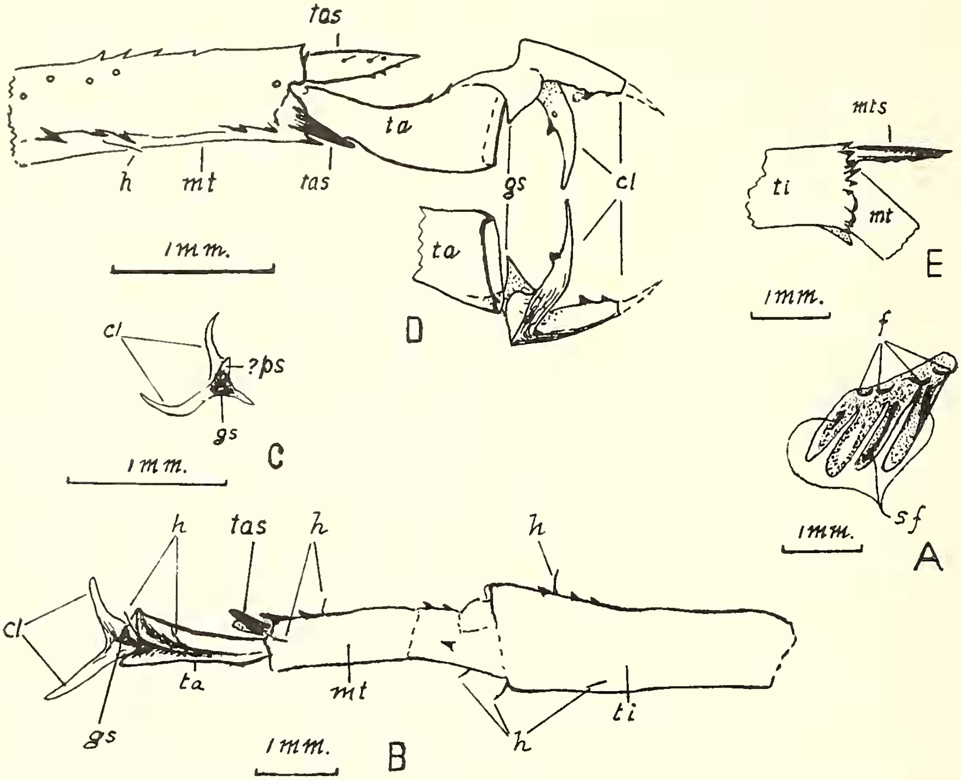
All the above features can be matched in large present-day scorpions, but there are certain minor differences in the structure of the claws and spurs.

(*a*) There are denticles along the inner edges of the claws (well seen in Slide 6 where the chitin is undamaged and unobscured by pyrites, Pl. 54, fig. 5; text-fig. 19D).

(*b*) Also there are small denticles or spines on some of the tarsal spurs and on the one metatarsal spur found (text-fig. 19E).

Both types of denticles are unknown in Recent scorpions, but occur in all the Carboniferous ones here described, except *B. buthiformis*.

(*c*) The pad (*Gehstachel*) of the claws of the ? 2nd leg (text-fig. 19C) appears to have been a conical structure not unlike the shortest type of 'dagger' in *Lichnophthalmus* (Part 1, text-fig. 8). It has a spine on one side that may correspond to one of the 'platform spines' of that genus. On the other hand, the



TEXT-FIG. 19. G.S.M. Za 2924. A, Slide 2924/2. The tip of R. comb. Plain areas, kaolin; stippled, chitin. The sensory field shown where visible. B, Slide 2924/1. End of 2nd L. leg with the metatarsus restored to its original position. Note uncrushed tarsus and setae still projecting from the skin at right angles. C, Slide 2924/1. Claws and pad (*Gehstachel*) of 2nd L. leg drawn looking down on the conical pad, with a possible platford spine. D, Slide 2924/6. End of 1st L. leg, to show denticles on the two claws and on one of the tarsal spurs, and details of setae and spines. E, Slide 2924/4. Parts of tibia and metatarsus of ? 3rd L. leg, to show the spiny end of tibia and slightly denticulated metatarsal spur of triangular cross-section. For key to abbreviations see p. 277.

pad on the ? 1st leg (text-fig. 19D) has no spine and in general resembles a large *Gehstachel* of a Recent scorpion.

(*d*) There are minute sensory hairs on one of the tarsal spurs on Slide 6 while the other smaller spur seems to be quite bare. Hairs are, I believe, unknown on the spurs of Recent forms, but have been seen on spurs and/or claws in *Pareobuthus* (Wills 1925, text-fig. 3A), *Mazoniscorpio* (Pl. 50, fig. 4), G.S.M. Za 2925 (text-fig. 22), and in *Lichnophthalmus* (they are not referred to in my description in Part 1).

(*e*) This animal may have had sensory hairs on its claws, since all the forms mentioned above have them, but the tips of those extracted are either broken or heavily encrusted with pyrites, and no hairs or hair-bases can be seen.

The pecten (Pl. 54, figs. 1–3). Both combs of the pecten were preserved, detached from the rest of the body, and in a somewhat crumpled state, yet with the teeth curved and overlapping as in life. The chitin has been reinforced by kaolin which fills the inside of the teeth and preserves their original shape, but it is in many places encrusted by pyrites. One comb was partly obscured and distorted by the end of the 2nd L. leg which lay across it (Pl. 54, fig. 2). Both were slightly damaged in mounting (Slides 1, 2), but the structure of the dorsal and ventral sides are excellently shown by the several fragments, and the whole can be rearranged, as has been done on Pl. 54, figs. 2, 3.

The combs were large, each measuring at least 5 mm. in length. The rachis of each is somewhat folded and broken. It is impossible to see its shape, but the chitin of which it is composed consists of irregular polygonal areoles of thicker or darker skin, sometimes carrying a hair-base, surrounded by thinner or lighter skin. This is exactly the arrangement on parts of the rachis of *Pareobuthus* (Wills 1925), *Lichnophthalmus* (Part 1), and *Buthiscorpius* (above), and of the other Carboniferous 'scorpions' mentioned in discussing the comb of *Lichnophthalmus* in Part 1, p. 274; and it would appear to be the structure depicted by Petrunkevitch's sketches of *Eoscorpius typicus* (Petrunkevitch 1913, fig. 7) and of *Isobuthus rakovnicensis* (Petrunkevitch 1953, fig. 19). The arrangement is analogous to the papillae carrying hairs on the combs of some Recent scorpions.

The teeth are long and, being preserved in the round, appear unusually narrow when compared with others described in this paper that are crushed. At least fifteen are attached obliquely to each rachis with a row of lappet-like fulcra covering the attachment. The fulcra and teeth alternate, each of the former overlapping the two half-bases of adjacent teeth (text-fig. 19A). A sensory field of peg-organs, as described in *Lichnophthalmus* (Part 1, p. 275), can be recognized on the teeth where the chitin is unobscured by pyrites. The kaolin infilling of the teeth bears minute polygonal markings, presumably recording a cellular inner layer of chitin patterned by the nerve-endings that supplied the peg-organs. (It may, however, only reflect the microcrystalline structure of the kaolin.)

Unidentifiable 'scorpion', G.S.M. Za 2925

Plate 55; text-figs. 20–22

Remarks. This specimen, as received, bore the label '? *Anthracoscorpio*, Trowell Colliery', and the Survey catalogue states that it came from above the Kilburn Coal which is taken as the base of the Ammanian in the Nottinghamshire Coalfield.

The specimen originally showed a dorsal view of ? a fragment of the carapace, the six tergites of the mesosoma, the dorsal plate of segment XIII, and some bits of appendages of a largish scorpion, but it had been broken off obliquely so that most of the carapace and parts of the first three tergites and the whole tail had been lost. On both sides of the animal lay long fragments of some plant (Pl. 55, figs. 1, 2).

I etched it and extracted a number of pieces now mounted as Slides 1–13 (Za 2925/1–/13), but the excellent Marco-cast that I had obtained was accidently burnt. As a result there is nothing except two photographs against which the following observations can be checked. Plate 55, fig. 2, taken in air shows more clearly the segmentation, whereas fig. 1 records better the distribution of the remnants of chitin (dark patches).

Although parts of the sternites, of the pecten, and of three or four legs were etched out and mounted, and now show interesting details described below, the absence of the prosoma with the carapace, sternum, and coxae makes exact identification impossible.

Description. Dorsal surface of the abdomen

Tergites. Behind a fragment of the carapace the six tergites of the mesosoma with tergal plate XIII (Pl. 55, figs. 1, 2) measured *c.* 20 mm. in length. Each tergite was bounded by a linear anterior margin and an ill-defined posterior margin with infolded doublure (text-fig. 20). Their greatest width at Tx is about 13 mm. The last tergite and the front of the tergal plate XIII are each *c.* 10 mm. wide and the hind end of the latter is *c.* 6 mm. across. The animal had been squashed flat, and for that reason the fossil appeared to be broader than it was in life, and wider than normal in relation to its length.

Ventral surface of the abdomen

Sternites. The ventral skin had been pressed against the dorsal during fossilization, but only the impression of the linear anterior margins of the four sternites IX–XII and of the sternal plate of segment XIII are traceable on the photos (Pl. 55, fig. 2), on which text-fig. 20 has been based. Two fragments believed to be parts of sternites were recovered (Slides Za 2925/6, /10). They are made of excessively thin skin which in parts is in two superimposed sheets. One, presumably the exterior, is uniformly transparent and carries along its edge a few diminutive granules and one or two tiny hair-bases; the other is blotchy. The supposed exterior sheet has a narrow doublure (? posterior margin), where it is seen by itself in Slide Za 2925/6 (text-fig. 21A), but in the double part the doublure seems to merge into the internal sheet. To the right (in the figure) the doublure and the internal sheet appear to separate and form a possible stigma leading into the space between the sheets—an arrangement reminiscent of the stigmata on the doublure of the sternites of *Mesophonus* (Wills 1947, pp. 26–35). However, the specimen is very fragmentary and nothing reliable can be deduced from it. The same applies to the second mount (Slide Za 2925/6; text-fig. 21B) where a somewhat similar structure can be made out at both ends. It must be recalled that at the postero-lateral corners of a sternite there is a complex concertina folding of the intersegmental and interpleural skin, and it may well be that this is what we see in these two specimens.

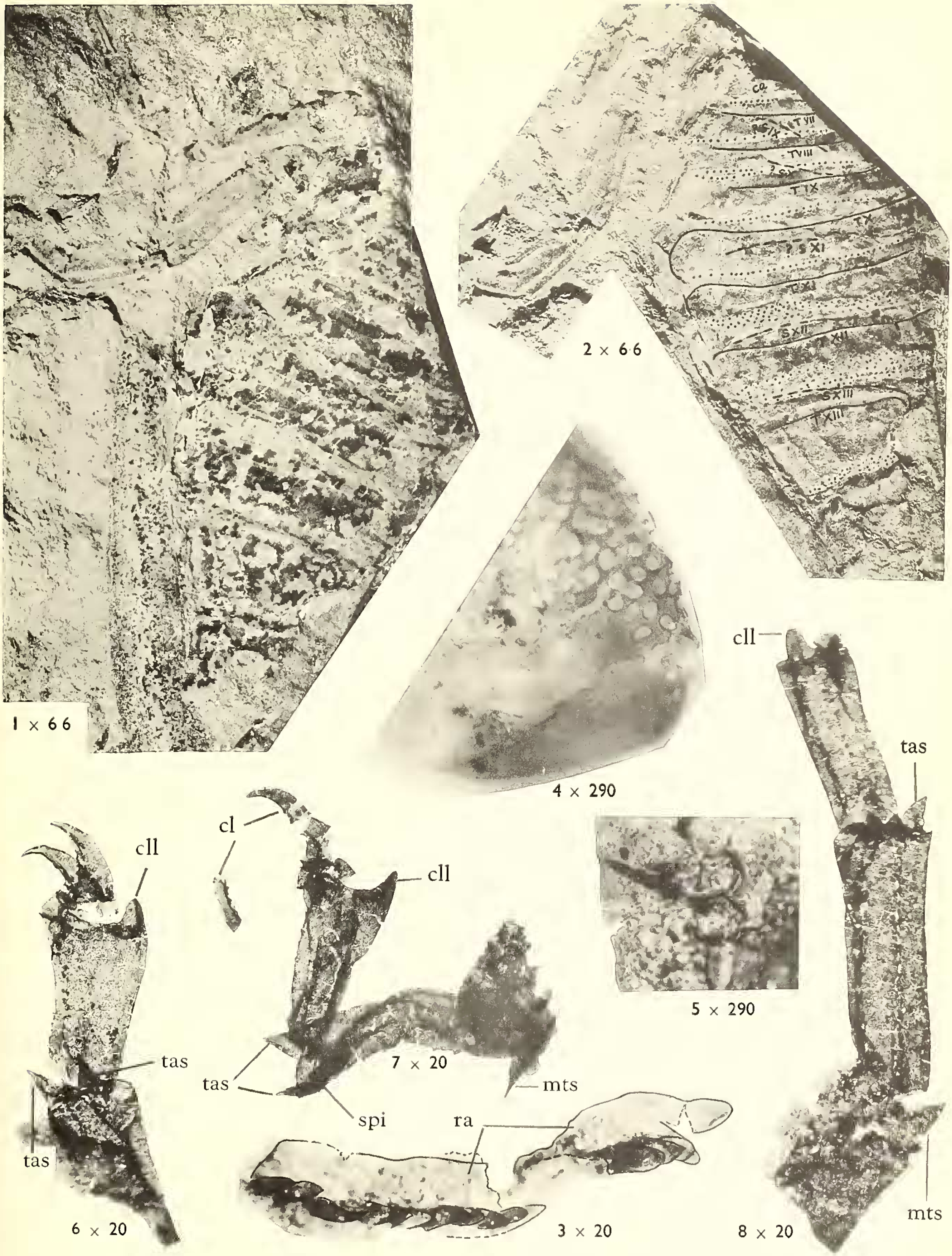
Prosomatic appendages

Legs. Parts of two legs lay exposed on the left side of the specimen as received (Pl. 55, figs. 1, 2; text-fig. 20), but it is impossible to say with certainty to which legs they belong.

EXPLANATION OF PLATE 55

Figs. 1–9. 'Scorpion', *indet.*, G.S.M. Za 2925. 1, As received, photographed under alcohol. The dark patches are chitin. ×6·6. 2, As received, photographed in air, features accentuated in ink (cf. text-fig. 20)—continuous lines, anterior margins of tergal plates TVII–TXIII; dotted areas, posterior marginal infolds of carapace and tergal plates; broken lines SIX–SXIII, supposed anterior margins of sternal plates. ×6·6. 3, Postero-ventral view of L. comb with rachis and teeth outlined in ink. ×20. 4, Tip of the last tooth of the comb, showing sensory field of peg-organs on one side only. Slide Za 2925/5. ×290. 5, Sensory hair (? trichobothrium) attached to hair-base, and a second hair-base on the other surface of the rachis. Slide Za 2925/5. ×290. 6, Metatarsus, tarsus and claws of 2nd or 3rd leg. Slide Za 2923/3. ×20. 7, End of tibia with metatarsal spur, metatarsus, tarsus, and claws (one detached) of ? 3rd leg. Slide Za 2925/4. ×20. 8, End of tibia with metatarsal spur, metatarsus, and tarsus with claw-lobe but minus claws; ? 4th leg. Slide Za 2925/2. ×20.

For key to abbreviations see p. 277.



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